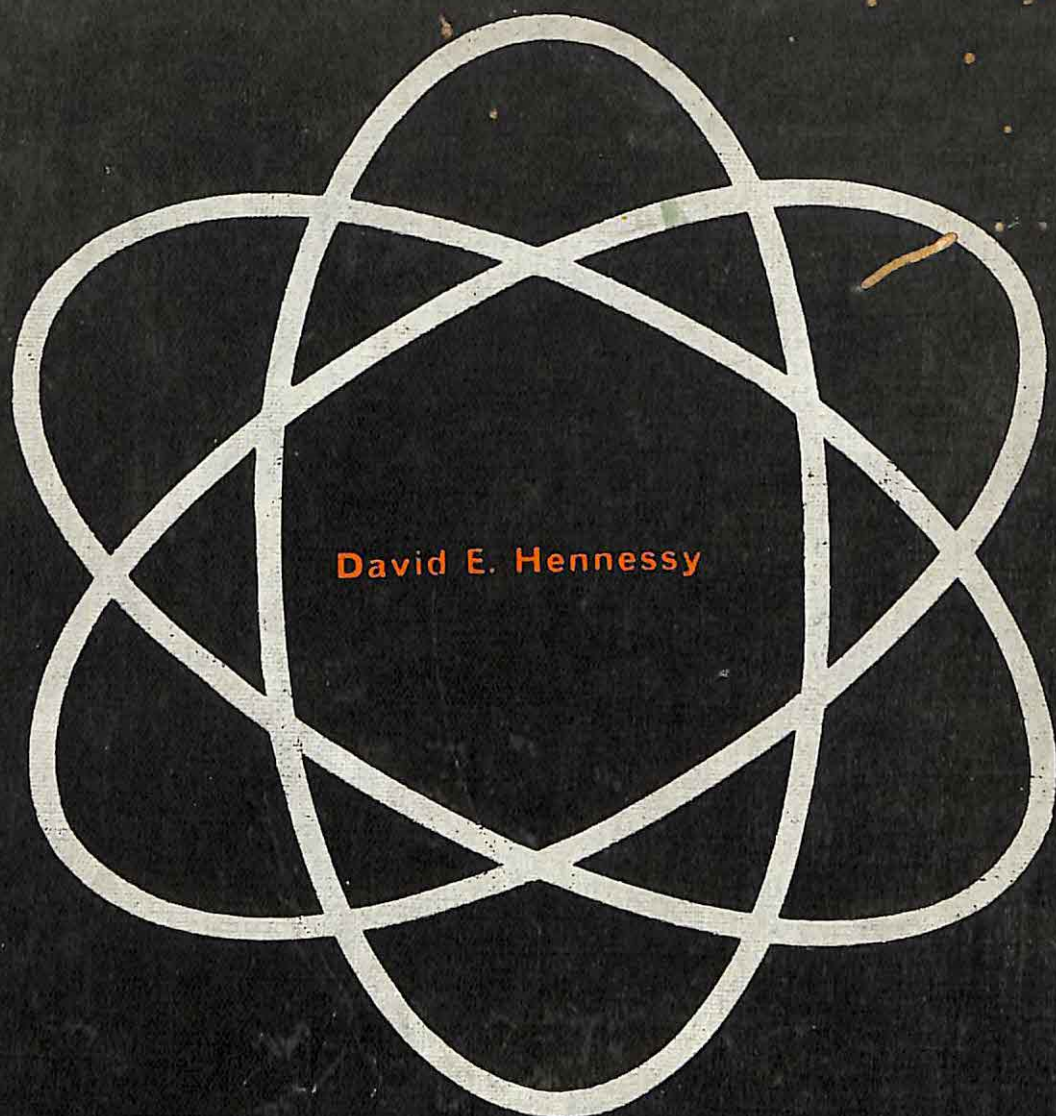
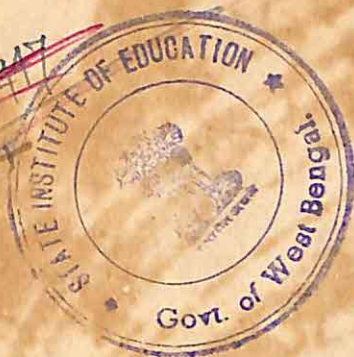




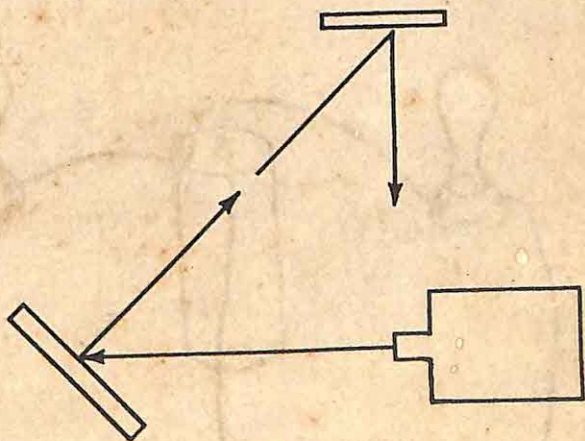
David E. Hennessy

**Elementary Teacher's
CLASSROOM SCIENCE
DEMONSTRATIONS
and ACTIVITIES**

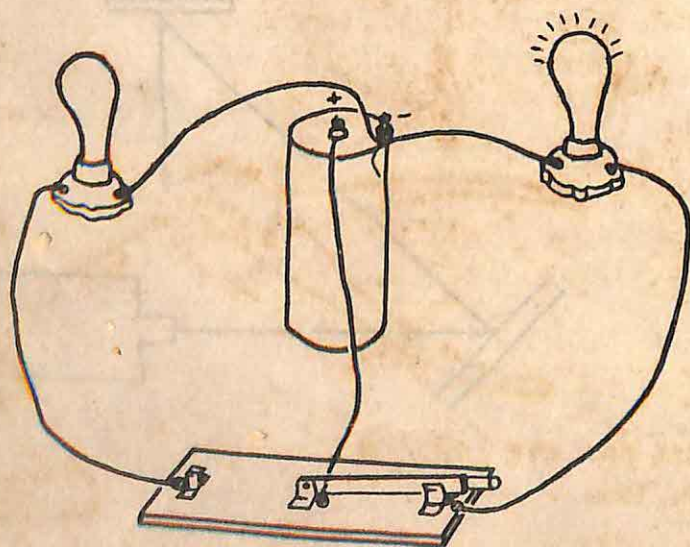


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ELEMENTARY TEACHER'S CLASSROOM SCIENCE
DEMONSTRATIONS AND ACTIVITIES



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DEMONSTRATIONS
AND ACTIVITIES



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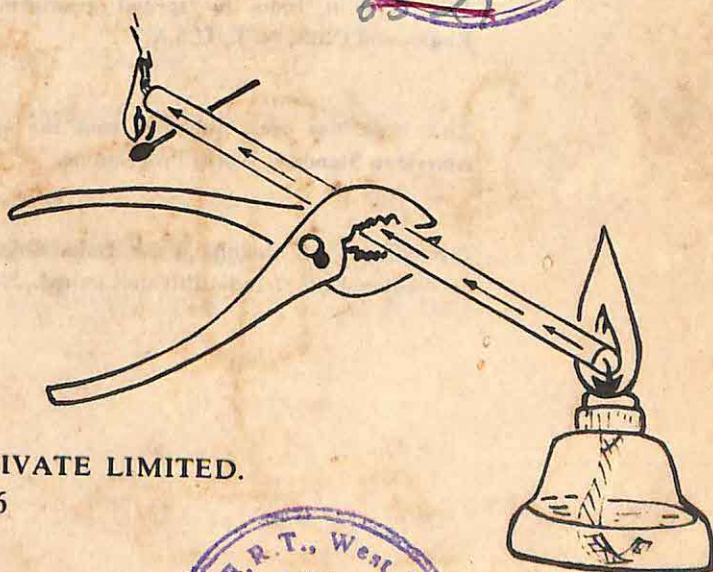
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ELEMENTARY TEACHER'S CLASSROOM SCIENCE
DEMONSTRATIONS AND ACTIVITIES

by David E. Hennessy

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To My Two Little Scientists
NANCY AND CINDY

Love Always
Dad



Introduction

Elementary Teacher's Classroom Science Demonstrations and Activities has been prepared to specifically provide the classroom teacher with readily available science demonstrations and student activities which can be incorporated into any elementary science program.

The book has been divided into several areas of science which are considered of general interest to all children at the elementary school level.

The author has incorporated in this book a suggested sequential order for presentation of the material in the various areas of science which will help the teacher plan her units and daily lesson plans.

Suggestions as to grade level of instruction for the various demonstrations and activities will be indicated but should not be interpreted to mean that they are limited to a particular grade level. The final decision is, of course, that of the teacher who is planning the science program to suit her children's needs.

The demonstrations and activities have all been tested in many school situations and emphasize the use of readily available, inexpensive materials and equipment such as the jelly jar, coffee can, milk carton, thread, string, wire and balloon. With the exception of equipment such as light bulbs, sockets, dry cells and a few other factory-made devices, most of the equipment can be gotten by the children at home, from the school custodian, from the local junkyard, or the teacher can bring them from home herself. Putting these materials together awaits only the imagination and ingenuity of the teacher and her students.

DAVID E. HENNESSY

Introduction

The purpose of this book is to provide a comprehensive overview of the various aspects of the human mind and its functions. It is intended for students and researchers alike, offering a blend of theoretical insights and practical applications. The book is organized into several chapters, each focusing on a specific area of study. The first chapter introduces the field of psychology, discussing its history and the various branches that have emerged over time. Subsequent chapters delve into topics such as perception, learning, memory, and emotion, each supported by scientific research and real-world examples. The final chapter explores the application of psychological principles in everyday life, from education to mental health. Throughout the book, the reader is encouraged to think critically and to apply the concepts learned to their own experiences.

The book is written in a clear and accessible style, with complex ideas explained in simple terms. It includes numerous examples and illustrations to help readers understand the concepts being discussed. The authors have drawn on a wealth of research to provide a solid foundation for the material presented. The book is a valuable resource for anyone interested in the human mind and its capabilities. It is hoped that this introduction will serve as a useful guide for readers as they explore the fascinating world of psychology.



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I

Living Things—Plants

Of paramount interest to children of the elementary school age in the study of science are plants.

Children in the elementary school age group are curious to know and investigate how plants grow, why they grow where they do, what makes them grow, and why plants are important to them.

Elementary school children are curious and like to investigate things that change, especially things that change rapidly enough for them to observe those changes taking place. Growing plants satisfy this interest and should be capitalized on by the elementary teacher in the classroom.

The study of plants can provide the teacher with a good opportunity to introduce students to several techniques used by research scientists in making quantitative studies. A quantitative study ascertains "how much" as compared to a qualitative study, which ascertains "what it is." In this chapter the techniques of estimating and sampling will be introduced in a quantitative study of weed seeds entitled "How Many Seeds are There?"

A. EXPERIMENTING WITH PLANTS

1. Plants Need Sunlight to Grow (Activity K-3)

Materials: Four empty cans, garden soil, and corn seeds or lima bean seeds.

Procedure: Plant four or five seeds in each can of garden soil and allow them to grow several inches tall. Place two cans with plants in a dark place and two cans with plants in the sunlight. Give all plants water as needed and observe what happens. Keep a written record of your observations by writing down or by drawing pictures of what you see, using color crayons to note any change in the color of the plants.

Discussion: The plants in the dark gradually become light in color and eventually will die from a lack of the sunlight needed to help produce food in the leaves.

Warning: Some commercial seeds are covered with poisonous insecticides to protect them from insects. This information may be ascertained from the information written on the package of seeds.

2. Plants Will Grow Towards Light (Activity K-3)

Materials: Milk carton covered with black construction paper, shoe box, two empty cans, garden soil, and lima bean seeds.

Procedure: Plant three or four seeds in each can filled with garden soil. Allow the bean sprouts to grow about two inches tall; then pull out all but one in each can. Cut a hole in the side of the milk carton and place it over one bean sprout as shown in Figure 1.1. Place the other plant inside the shoe box with a hole cut in the far end as shown in Figure 1.1. Provide several partial partitions in the shoe box as shown. Observe each plant about every other day and record what is observed.

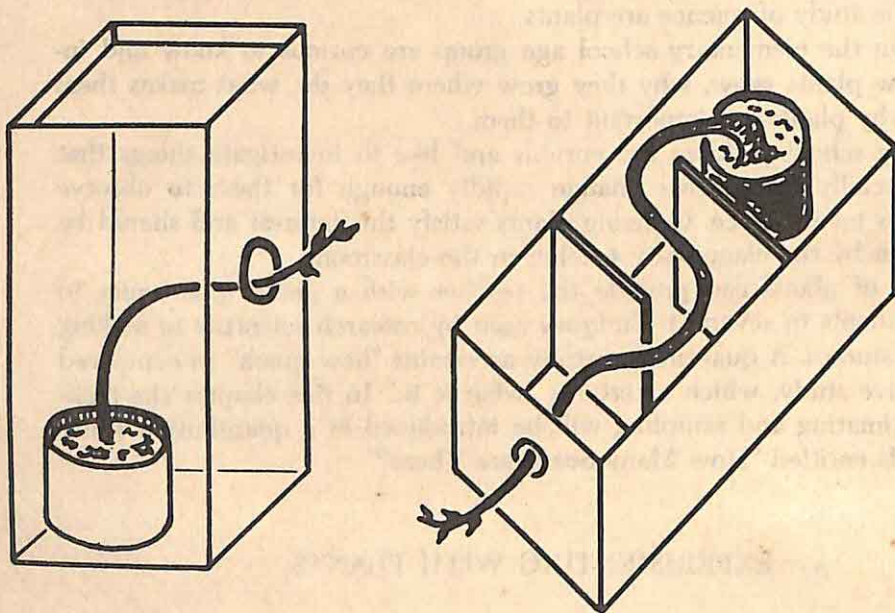


Figure 1.1

Discussion: Both plants will grow toward the hole admitting the light. The plant in the shoe box will grow around the partitions. Be sure that the cover in the shoe box is tight, or the plant will grow over the partitions instead of around them. Observe what happens to the plant when the hole in the milk carton is turned in another direction.

3. Plants Need Water to Grow (Activity K-3)

Materials: Four empty cans, garden soil, and corn seeds or lima bean seeds.

Procedure: Plant four or five seeds in each can of garden soil and allow the plants to grow several inches tall. Water two of the cans of growing plants as needed but do not water the other plants. Be sure all plants get sunlight and air. Observe and record your observations.

Discussion: The plants that are not watered eventually dry up (dehydrate), turn brown, and die.

4. Observing Plants in Garden Soil and Sandy Soil (Activity K-3)

Materials: Four empty cans, garden soil, sandy soil, and corn seeds or lima bean seeds.

Procedure: Plant four or five seeds in each of two cans of garden soil. Plant four or five seeds in each of two cans of sandy soil. Provide each can of seeds with adequate light, water, and air. Observe and record your observations.

Discussion: The seeds in each can begin to sprout at about the same time and for a few days continue to grow at the same rate. This is because the young sprouts are using the food stored in the seed itself (cotyledonous) for early growth while the roots are developing. By the time the young sprout has used up most of the seed nourishment, the roots have developed enough to carry out their function of absorbing dissolved minerals from the soil for the plant to use in its process of growth. Garden soil usually holds more of the minerals required for plant growth than does sandy soil. Don't be surprised if the reverse happens. If it does, use this opportunity to discuss why it happened and try the experiment over again with a new source of soil.

5. Observing Sprouting Seeds in Soil (Activity K-3)

Materials: Glass jars, garden soil, corn seeds, and lima bean seeds.

Procedure: Fill each jar with garden soil and push several seeds into the soil so that they are against the glass of the jar and can be easily seen. Add some water to each jar to moisten the soil. Be sure not to over water. Too much water could cause the seeds to rot. Observe and record your observations by drawing pictures of what you observe each day.

Discussion: The seeds will begin to sprout with the roots growing down and the stems growing up. Other observations could also be made, such as: that the two cotyledons of the lima bean seed (dicotyledonous) will grow out above the soil as compared to the single cotyledon of the corn seed (monocotyledonous), which will remain under the soil. The children may also observe what happens to the cotyledons themselves after the plant has become well developed.

6. Observing Sprouting Seeds in Water (Activity K-3)

Materials: Glass jar, cotton, corn seeds, and lima bean seeds.

Procedure: Fill a small jar with cotton and place several seeds in the cotton so that they may be observed through the glass of the jar. Moisten the cotton but do not flood the jar. If lima bean seeds are used, split one apart each day and observe what happens to them as they grow. Record your observations.

Discussion: The seeds will sprout and the growth of the roots and stems can be easily observed. Another observation which might be made is the growth of root hairs. These are the tiny roots which grow out from the main roots.

7. Observing Sprouting Seeds in Water (Activity K-3)

Materials: Glass jars, blotter paper, corn seeds, and lima bean seeds.

Procedure: Cut a sheet of blotter paper and bend it into a cylinder which fits snugly against the inside of the glass jar. Insert the seeds between the blotter paper and the glass wall of the jar so that they may be observed through the glass. Add some water to the jar but do not fill the jar. Record your observations.

Discussion: The seeds will sprout, and the growth of the roots and stems can easily be observed. A study of the root hairs can also be made in this activity.

8. Seeds Provide Food for Sprouting Plants (Activity K-3)

Materials: Glass jar, water, corn seeds, lima bean seeds, and a hand lens.

Procedure: Soak some corn seeds and lima bean seeds overnight in a jar of water to soften the skin of the seeds. Remove the skin and see if you can find the seed plant and the food for the tiny plant.

Discussion: The children can observe the three parts of the seed: the skin, the tiny plant, and the food. The tiny plant of the lima bean seed can be found by separating the two cotyledons. A hand lens will show it very clearly. Each cotyledon provides stored food for the tiny plant and is protected by the skin of the seed. If you perform activity number 5, you will be able to observe the food of each cotyledon being used up by the growing plant. The tiny seed plant of the corn seed is smaller than that of the lima bean seed and can be seen underneath the seed's skin by using a hand lens. The corn seed is a *monocotyledon*, having only one *cotyledon*. After the plant has grown several inches, the stored food in the single cotyledon will be used by the plant, and the protective skin will appear empty and shriveled.

9. Observing Plant in Airtight Chambers (Activity K-3)

Materials: Two quart jars, corn seeds, and garden soil.

Procedure: Fill two quart jars half full with good garden soil. Plant four or five corn seeds in each jar and allow them to grow about three inches tall. Place the cover on one of the jars and screw it on tightly to make it as airtight as possible. Observe what happens to the corn plants in the covered jar and the uncovered jar. Do not place the jars in the direct sunlight. Record your observations.

Discussion: Air is essential to the growth of plants. The corn plants in the covered jar will eventually stop growing and die. The supply of carbon dioxide, which is present in the atmosphere and essential for the process of food making in the leaves, is cut off when the cover is placed over the jar, and the growth of the plant is stunted. Oxygen is essential to the respiration of the roots in the soil and in the respiration of the cells of the leaves and stems of green plants.

10. Observing Growing Bulbs (Activity K-3)

Materials: Two onions, two jars, water, and toothpicks.

Procedure: Pierce the sides of the onions with several toothpicks, allowing about half their total length to protrude from the sides of the onion. Set the onions over the mouths of the jars so that the toothpicks support the weight of the onions. Fill the jars with water so that the base of the onion is submerged. Add water as needed to keep the level of the water up to the base of the onion. Record your observations.

Discussion: Roots will grow downward into the water, and the green leaves will start growing upward. The children will observe the growth of the roots too. Where is the young plant getting its food? From the bulb. The bulb will become soft and shrink in size as the onion plant grows.

11. Observing Potatoes Grow (Activity K-3)

Materials: Potato, two jars, water, and toothpicks.

Procedure: Cut the potato into two parts, making sure that there is a potato eye in each part. Pierce the sides of the potato parts with toothpicks, allowing about half their total length to protrude from the sides of the potato. Set the potato over the mouth of the jars and cut surface downward so that the toothpicks support the weight of the potato. Fill the jars with water so that the cut surface of the potato is submerged in water. Add water as needed to keep the cut surface of the potato in water. Record your observations as before.

Discussion: The potato sprouts will begin to grow upward, and the roots from these sprouts will begin to grow downward toward the water. The new plant will get its initial food from the potato, which eventually becomes soft and decays.

12. Making a Data Collecting Sheet (Activity 2-6)

For the children to collect data from their experiments and record their observations, the form shown in Figure 1.2 has proven useful.

Figure 1.2

NAME OF EXPERIMENT		DATE STARTED
DATE	WHAT HAPPENED	OBSERVER
DEC. 5, 1963	SPROUT BROKE SURFACE	



B. WORKING WITH TERRARIUMS AND PLANTS

1. Building a Terrarium (Activity K-6)

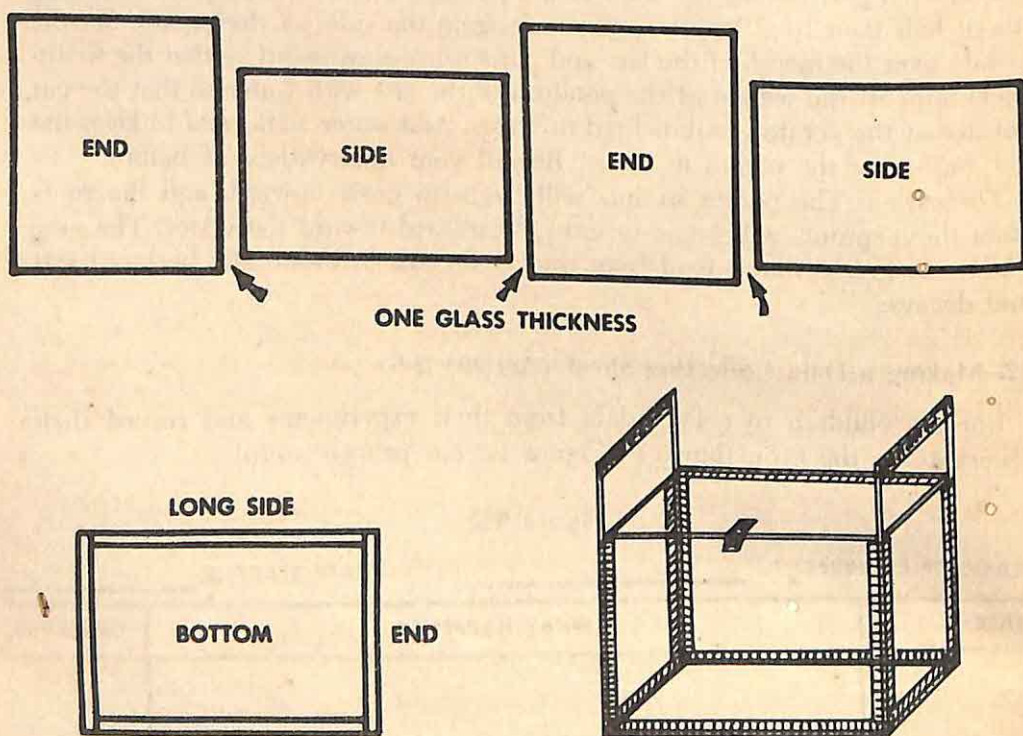
Materials: Six sheets of single strength window glass 10 × 12 inches and one roll of 1 inch wide adhesive tape.

Procedure: Arrange four sheets of glass as shown in Figure 1.3, making sure that the tall ends overlap the long sides by one thickness of the glass. Be sure that there is one glass thickness between each two sheets of glass.

Tape the sides and ends together with 1 inch width adhesive tape. With the help of another student lift the sides and ends up and form a box so that the taller ends are outside the long sides, as shown in Figure 1.3, and tape the edges of the side and end together. Invert the box so that it is standing on the taller ends and insert the bottom glass so that it overlaps the long sides and fits flush with the tall ends. Tape the bottom to the sides and ends. Now do you see why we overlapped the long ends one glass thickness?

Invert the box so that it is sitting on the bottom and insert the cover so that it fits between the two ends and is supported by the long sides. Using tape, hinge the cover to one long side. For convenience in opening and closing the cover, place a tape handle on it. For safety in handling the terrarium, tape the exposed edges of the ends and sides but be sure not to allow the tape to interfere with the opening and shutting of the cover.

Figure 1.3

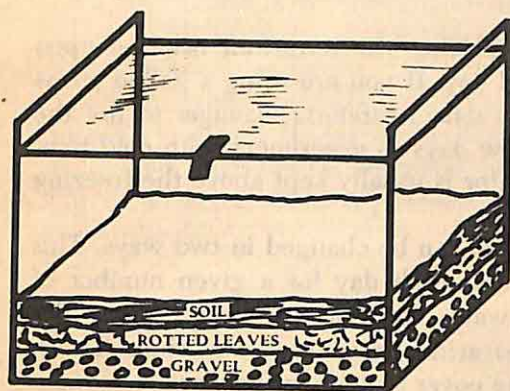


Discussion: This type of terrarium provides a well-built glass laboratory for studying plants, climate, and animals.

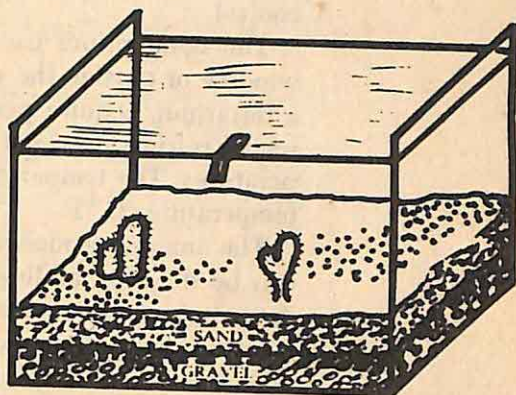
2. Preparing a Terrarium for Experiments With Plants and Climate (Activity K-6)

Materials: Terrarium, coarse gravel, rotted leaves, soil, sand, and plants.

Procedure: Arrange the materials in the terrarium as shown in Figure 1.4. Terrarium "A" is for plants which grow in fertile soils. Terrarium "B" is for cactus plants which grow in sandy desert areas.

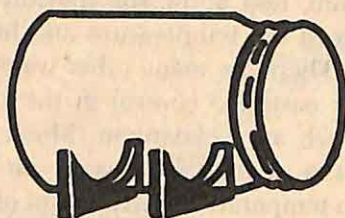


TERRARIUM "A"



TERRARIUM "B"

Figure 1.4



JAR TERRARIUM

Discussion: These terrariums will provide two different soil environments to study various types of plants in different climates.

A large gallon mayonnaise or mustard jar can be used in a similar manner. The school cafeteria or a local restaurant may have a few of these gallon jars for you. Use modeling clay or specially cut blocks of wood as a base for the rounded jar as shown in Figure 1.4.

3. Experimenting With Plants and Climate in a Terrarium (Activity 4-6)

Materials: Terrarium, various plants, thermometer, electric light bulb, and relative humidity indicator.

Procedure: Plant the plants you have selected in the terrarium. There are many effortless ways of changing the climate inside the terrarium. The following suggestions are ideas which have been successful.

Raise the temperature in the terrarium by placing it in the direct sunlight. If the cover is left on, this will produce a hot, moist climate. If the cover is left off, the moisture will evaporate and the result will be a hot, dry climate. Use a thermometer to measure the temperature inside the terrarium and record your observations. Use a simple psychrometer to measure the relative humidity in the terrarium. (Refer to Chapter IV, "The Air Around Us," Topic "E" Weather Instruments for the construction of a simple psychrometer.) The use of sunlight to raise the temperature in the terrarium does not provide good control of the temperature. An electric light placed inside the terrarium or shining into it from outside will provide a more even and better temperature control.

The temperature can be lowered by placing the terrarium near an open window or outside the window on a cool day. If you are using a gallon jar as a terrarium, acquire permission from the school cafeteria manager to use the school refrigerator (*not freezer*) for a few days to experiment with cold temperatures. The temperature of a refrigerator is usually kept above the freezing temperature 32° F.

The amount of moisture in the terrarium can be changed in two ways. This can be done by adding an ounce of water each day for a given number of days, leaving the cover on so that the water will not evaporate rapidly. Remember that you are working with a terrarium and not an aquarium. To reduce the amount of moisture, remove the cover and allow the water to evaporate. Record the temperature and humidity.

To create a desert climate for a cactus plants, open the cover, heat the air in the terrarium, and allow the moisture to evaporate. Shut the cover once again and record the temperature and humidity.

Discussion: There are many other ways to change the climate in a terrarium. The climate is easier to control in the small area of the terrarium than in a larger area, such as a classroom. Much can be learned about the effects of climate and the change in seasons on various kinds of plants, at least in relationship to temperature and amount of moisture. A great deal can be learned about why certain plants grow where they do. Whatever experiments are performed, have the children make routine observations and keep a record of these observations. To make these observations more authentic, a Polaroid camera could be used to take and develop pictures of unusual happenings with quick results. If a Polaroid camera is not available in your school or if you are not already a "camera bug" yourself, call upon a student or fellow teacher who has had experience with a camera.

C. WORKING WITH NON-GREEN PLANTS

1. Growing Bread Mold (Activity 4-6)

Materials: Shallow dish, slice of bread, cardboard box, and hand lens.

Procedure: Place a slice of bread in a shallow dish and moisten it with water. Expose the bread to the air for several hours and then put it in the card-

board box with the lid on. Set the box in a warm, dark location in the room, observe it once each day, and record your observations.

Discussion: After several days, mold can be seen starting to grow as a fuzzy white substance which looks like dust. Examine the mold with a hand lens, and you will discover the tiny spore cases or *sporangia*. Some will appear like tiny white or black knobs with stems on them as illustrated in Figure 1.5. The spore cases contain a powder-like substance composed of tiny spores. The black cases contain the ripened spores and the white ones the unripened spores.

To investigate how bread mold reproduces, remove some of the *ripened* bread mold, place it on a freshly moistened slice of bread, and follow the same procedure as before.

Spores are like tiny dust particles which float in the air and can travel in many different locations. If they settle in the *right* place (the right place being warm, moist, and dark with a sufficient amount of the proper nourishment), they will grow. Bread mold is parasitic and does not produce its own food as do green plants.

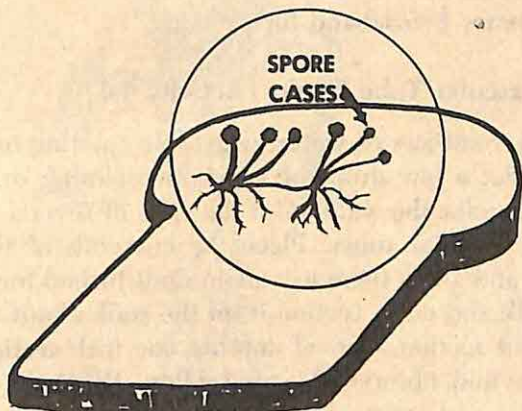


Figure 1.5

2. Mushrooms and How They Reproduce (Activity 4-6)

Materials: Some common gilled mushrooms, white paper, black paper, and a small box.

Procedure: Gather some common gilled mushrooms and very carefully separate the cap from the stalk. Place several caps, gills down, on some white paper and several on black paper. Cover the mushroom caps with a box or dish and allow them to remain undisturbed for a day or two; then remove them from the paper.

Warning: Many wild mushrooms are poisonous and should not be eaten.

Discussion: Black prints will be visible on the white paper if the mushrooms you gathered produced black spores. If the mushrooms you picked produced white spores, then white spore prints will be visible on the black paper.

Not all mushrooms have gills: some have pores in which the spores are

produced. The bracket fungi, commonly found growing from the sides of trees or on rotted logs and stumps, have pores on their undersides from which the spores fall when ripe.

D. PARTS OF THE GREEN PLANT

1. Vascular Tubes (Demonstration 4-6)

Materials: Celery stalks.

Procedure: Crush a stalk of celery at a point several inches from each end, being careful not to sever the stalk. Grasp each end and pull the stalk apart slowly.

Discussion: The crushed celery stalk will pull apart, exposing the vascular tube bundles. It is possible to pull these bundles free from one end of the celery stalk to expose them even more. The same demonstration can be performed with the common weed called *plantain*. (However, do not be misled by the dissociated walls of spirally-thickened xylem vessels which will often pull out to considerable lengths.) For assured success with the demonstration, try it several times beforehand for practice.

2. How the Vascular Tube Works (Activity 4-6)

Materials: Several jars of water, vegetable coloring or ink, and celery stalks.

Procedure: Put a few drops of vegetable coloring or ink in each of several jars of water to color the water. Cut the ends of several celery stalks to be sure to expose the vascular tubes. Place the cut ends of the celery stalks in the colored water and allow them to remain undisturbed for several hours. Remove one celery stalk and cut a section from the stalk about one inch from the end. Observe the cut section. Cut off another one inch section from the end of the stalk as before and observe the cut section. What do you observe about the vascular tubes as you continue to cut the celery stalk?

Discussion: The colored water has risen up the celery stalk by way of the vascular tubes as observed in the cross-section cuts illustrated in Figure 1.6.

As the celery stalk is cut closer to the leaves of the stalk, the coloring becomes less and less distinct but can still be seen. After a few more hours cut another celery stalk, only this time continue to cut the branches of the celery stalk which lead to the leaf blades. As the celery stalks remain in the colored water for longer periods of time, the coloring will become more prominently visible in the vascular tubes. Eventually the bleached leaves of the celery will become colored as well. It is the primary function of the vascular tubes to carry the water and dissolved minerals, absorbed from the soil by the roots, to the leaf blades where they are used in the food-making process of the leaves. Vascular tubes also serve as supporting tissue for some plants.

3. How the Vascular Tubes Work (Activity 4-6)

Materials: Several jars of colored water and celery stalks.

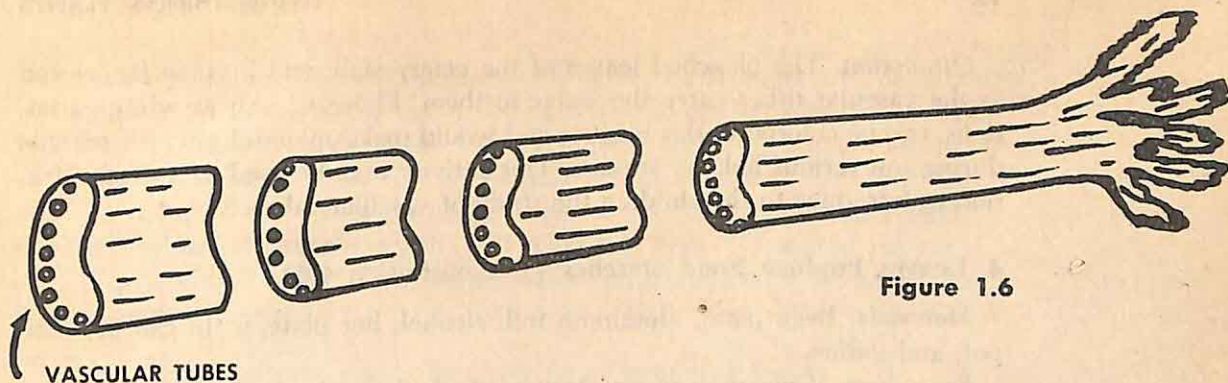
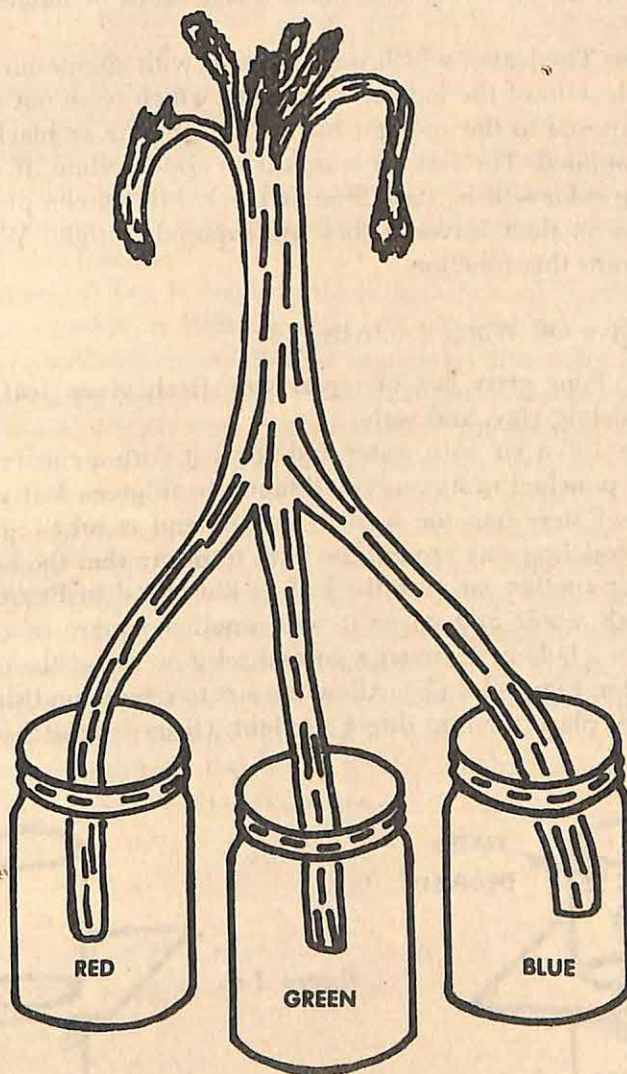


Figure 1.6

Procedure: Split a celery stalk with a knife into three longitudinal sections about four to five inches from the end and insert one section in blue colored water, one in red colored water, and the other in green colored water as shown in Figure 1.7. Allow them to remain undisturbed overnight.

Figure 1.7



Discussion: The bleached leaves of the celery stalk will become tri-colored as the vascular tubes carry the water to them. Flowers, such as white carnations, can be colored in this manner and would make splendid gifts for parents during the various holiday seasons. This activity may be used as a demonstration to introduce to the children the study of vascular tubes.

4. Leaves Produce Food Starches (Demonstration 4-6)

Materials: Bean plant, aluminum foil, alcohol, hot plate, a tin can or small pot, and iodine.

Procedure: Wrap each of two leaves *attached* to a bean plant in aluminum foil for several days. Two days is generally satisfactory. Detach these leaves and remove the aluminum foil. Boil both leaves in alcohol until most of the green chlorophyll is extracted from them. Remove the leaves from the alcohol, dry them gently with a paper towel, and squeeze a few drops of iodine on each leaf. What happens? Remove from the same bean plant two leaves which were exposed to light and not covered with aluminum foil and extract the chlorophyll in the same manner. Place a few drops of iodine on them. What happens?

Discussion: The leaves which were covered with aluminum foil showed only the brownish stain of the iodine. The leaves which were not covered with foil and were exposed to the sunlight turned a dark blue or black color when the iodine was applied. The test for *starch* is to apply iodine. If starch is present, the resulting color will be dark blue or black. Most green plants will produce *food starches* in their leaves if they are exposed to light. Without light they cannot perform this function.

5. Leaves Give Off Water (Activity 4-6)

Materials: Four glass jars of equal size, fresh green leaf, two cardboard squares, modeling clay, and water.

Procedure: Fill a jar with water and cover it with a cardboard square with a small hole punched in its center. Obtain a fresh green leaf with a long stem. Insert the leaf stem into the hole so that its end is submerged in the water. Pack some modeling clay around the stem to insure that the hole is completely closed. Invert another jar over the leaf as illustrated in Figure 1.8 (a). Fill a third jar with water and cover it with another square of cardboard which *does not* have a hole in it. Invert a jar and set it on top of the cardboard square as illustrated in Figure 1.8 (b). Allow the jars to remain undisturbed for several hours. Do not place them in direct sunlight. Observe what happens inside the inverted jars.

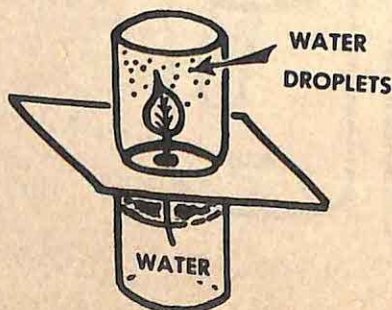
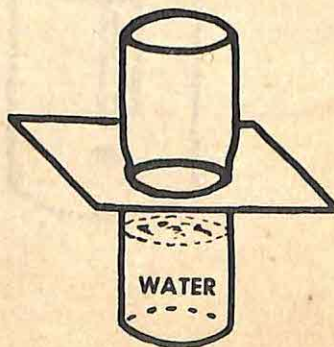


Figure 1.8



Discussion: The jar with the leaf in it will have small droplets of moisture on the inside. The jar without the leaf will not have any moisture in it. The moisture must have come from the leaf, since none could have come through the hole in the cardboard which was sealed with the stem and modeling clay.

As the pores of the leaves (stomata) open up to take in carbon dioxide, which is used in food making by the leaf cells, they give off water at the same time. This process is called *transpiration*. How can transpiration be dangerous to plants in dry weather?

E. IDENTIFYING AND COLLECTING PLANTS

1. Constructing a Key (Demonstration 4-6)

The word *key* to most children brings to mind a metal device used to unlock doors or padlocks and to provide access to homes, stores, school buildings, trunks, cars, or Dad's tool box.

Scientists use keys too but not always to open doors to their laboratories. They also use another kind of key to open the door to learning new and exciting things about the world around them. Specifically, they use keys for identification purposes. They use keys to identify animals, plants, rocks, fossils, etc. That is, they use the physical characteristics of these objects as stepping stones to the final identification of the object under study. Children in the elementary school can learn to use a simple key if they understand how one is constructed. The demonstration written and illustrated in the following paragraphs has proven successful in creating an understanding of the use of and construction of a simple key.

Explanation of a key: A key is divided into *steps* which ask "yes" and "no" questions. Steps also provide us with directions as to what to do next. Each step has two or more *questions* which ask us something about the object we are trying to identify. If your answer "yes" to a question, you will either have identified the object or told what step to go to next. If you answer "no" to the first question in a step, then you must read the second question under that step. Outline this procedure on the board for the children to see.

Making a simple key for practice: "I have in my hand three objects: a pencil, an eraser, and a plastic ruler. We all know what these things are, but let's pretend that we are scientists, and we have just discovered them. We would like to make a key so that other scientists who have never seen them will also be able to identify them. What characteristics can we use to identify them? A pencil—long and thin, made of wood. An eraser—made of rubber, square. A ruler—long and thin, made of plastic."

Outline these characteristics on the board as the children think of them. Using these characteristics construct a simple key as follows:

KEY

STEP ONE

Question 1. Is it long and thin and made of wood?—pencil.

Question 2. It is not made of wood—go to step two.

STEP TWO

Question 1. Is it long and thin and made of plastic?—ruler.

Question 2. It is not made of plastic—go to step three.

STEP THREE

Question 1. Is it square and made of rubber?—eraser.

After the key is constructed, practice using it to identify each object.

The introduction of keys could be started during the first week of school with the children and teacher constructing a key for learning their new classmates. This could be done by using the characteristics of the children in the classroom and dividing them into steps. The first step might separate *boys* and *girls*. The second step might break down the girls into those with dark or light hair, and so on, until each child was identified with his name.

2. A Key for Trees (Activity 4-6)

One way to put a key to good use is for the teacher and/or students to make a key for identifying the trees which are found on the school grounds. If a sample key is made by the teacher, it could be passed out to the students and a field trip conducted on the school grounds as an immediate follow-up activity. The following key might be used as a sample for constructing your own key.

SAMPLE KEY TO BE USED IN IDENTIFYING TREES

Directions for the use of the key.

This key is divided into four steps. Each step will ask two questions about a tree. Answer each question with a "yes" or a "no."

If your answer is "yes," then you either will have identified the tree or will be directed to the next step, which will help you to find out what tree it is.

If your answer is "no," then read the second question of that step. It will tell you which step to go to next.

STEP ONE

Question 1. Are the leaves like needles? (*Conifer*) They are! Then go to step two.

Question 2. If the leaves are not like needles, then they must be broad and flat like these. (*Deciduous*)

You may skip step two and go on to step three.

STEP TWO

Question 1. Do the needles grow singly and are they short and difficult to roll between your fingers (like your six-sided pencil)? Oh boy! You are lucky. You have just found a spruce tree, a yaw, a juniper, or a hemlock tree. Another key would have to be constructed to separate these types of conifers.

Question 2. Or are the needles long, growing in bundles of two or three together? They are! Then you have identified a pine tree.

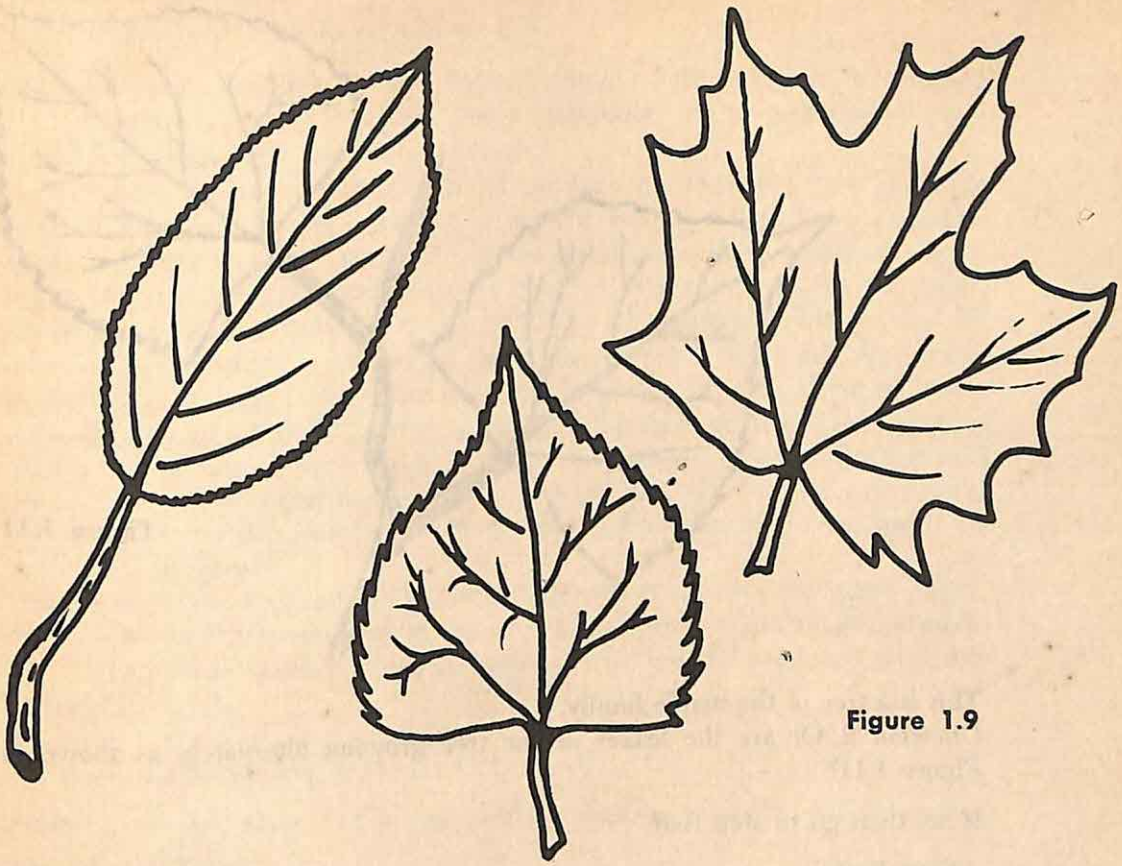


Figure 1.9

STEP THREE

Question 1. Are the broad leaves of the tree growing opposite each other, as in Figure 1.10?

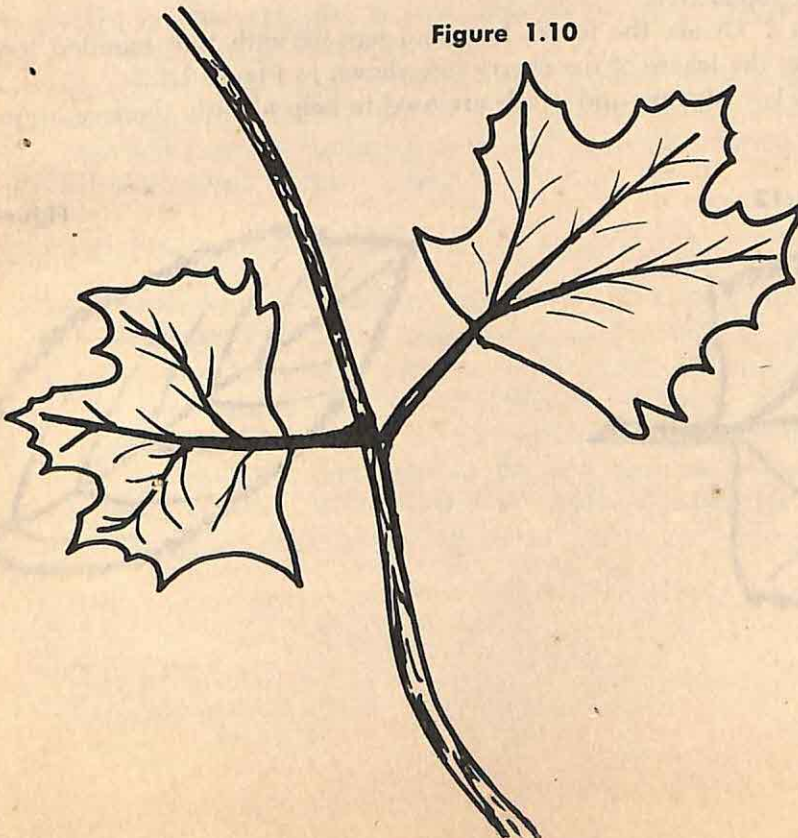


Figure 1.10

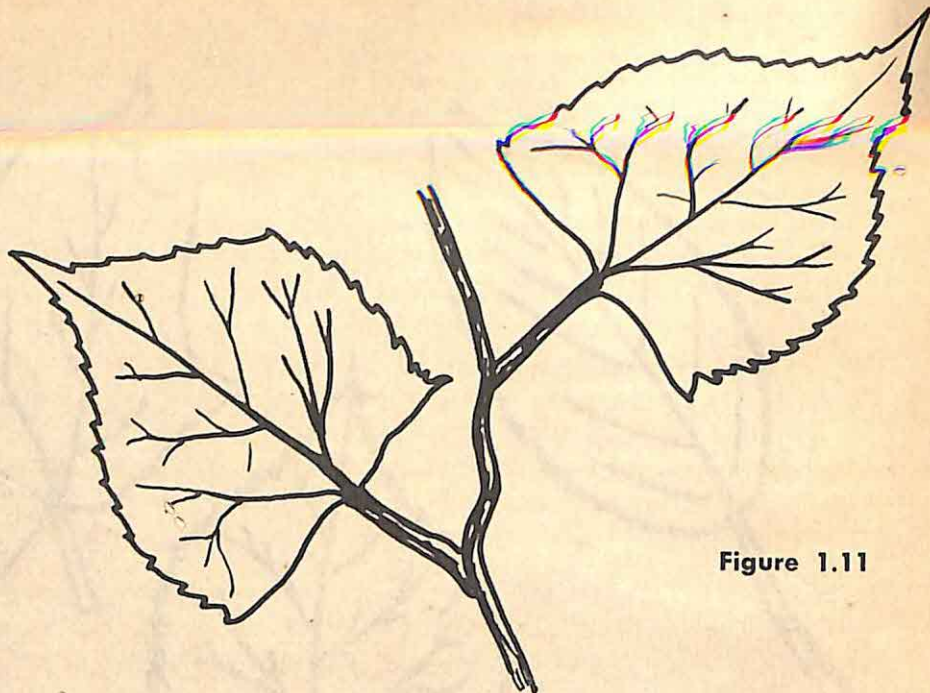


Figure 1.11

This is a tree of the maple family.

Question 2. Or are the leaves of the tree growing alternately as shown in Figure 1.11?

If so, then go to step four.

STEP FOUR

Question 1. Are the leaves wide near the middle with small rounded tooth-like edges as shown in Figure 1.12?

This is a poplar tree.

Question 2. Or are the leaves long and narrow with tiny rounded tooth-like edges like the leaves of the cherry tree shown in Figure 1.13?

In this key pictures and words are used to help identify the tree in question.

Figure 1.12

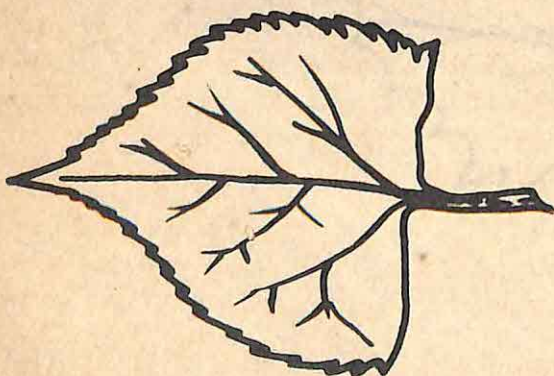
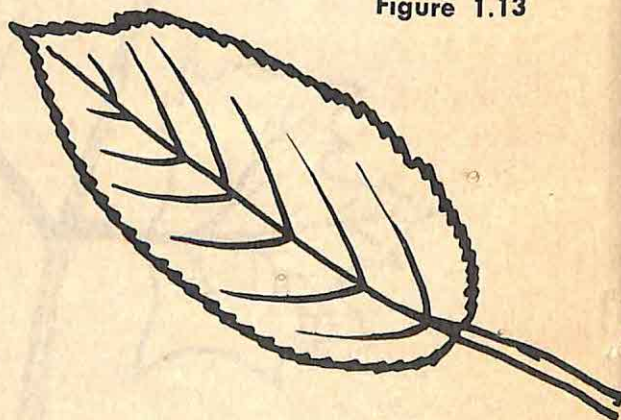


Figure 1.13



3. Making a Leaf Print Key (Activity 4-6)

Materials: Printer's ink in tube, rubber printer's roller (brayer, if ordering from a printer's supply catalog), pane of window glass, newspaper, plain white notebook paper, and leaf specimens.

Procedure: Squeeze an inch or so of printer's ink from the tube onto the pane of glass and spread it evenly, using the rubber roller. Take a freshly-picked leaf specimen and lay it flat on the inked glass. Place a sheet of newspaper over the specimen and roll over the leaf several times with the roller, applying moderate pressure. Remove the sheet of newspaper, lift the leaf by its stalk, and carefully lay it flat on the white notebook paper ink side down. Be sure that you place the white notebook paper on top of a sheet of newspaper to prevent ink smudges from getting on the table or desk. Place another clean sheet of newspaper on top of the leaf specimen to cover both it and the entire sheet of white notebook paper. Now roll over the leaf once again with the rubber roller. Remove the newspaper and gently lift the leaf specimen from the white paper.

Discussion: An ink print of the entire leaf will be left on the white paper, showing in detail the venation of the leaf. These prints could easily be made into a picture key booklet. Prints of various colors can be produced with different colored ink.

4. Preserving Specimens in Wax (Activity 4-6)

Materials: Hot plate, coffee can, sealing wax, newspaper, pair of pliers, and leaf specimens.

Procedure: Using an electric hot plate, melt some sealing wax in a coffee can. Grasp the leaf stem with the pliers, making sure to hold the pliers as close to the end of the handles as possible. Dip the leaf in the melted wax and remove quickly to allow the wax to cool and harden. The process may be repeated if a thicker coat of wax is desired.

Discussion: The leaf will be preserved for a long period of time in a hard coating of wax. Colorful fall leaves can be preserved in this way so that they will retain their color. Avoid damaging the waxed leaves by storing them in a box padded with cotton or tissue paper.

5. Making a Leaf Press (Activity 4-6)

Materials: Several corrugated cardboard squares of equal size (2 foot square works well), newspaper, some heavy duty rubber bands, and leaf specimens.

Procedure: Cut the sheets of newspaper to the same dimensions as the corrugated cardboard squares. Put several sheets of newspaper on top of a cardboard square and carefully place the leaf specimens on top of the newspaper, making sure that the specimens lie flat and have no turned under corners. Cover the specimens with several more sheets of newspaper and another sheet of corrugated cardboard as shown in Figure 1.14. Wrap several

rubber bands around the package to hold it together and then apply some weight. Several layers can be piled on top of each other.

Discussion: You have constructed a leaf press which will squeeze the fluids from the leaves and speed drying. To speed drying further, change the newspaper layers in the press every day. As the fluids are squeezed out, the layers of paper absorb the moisture.

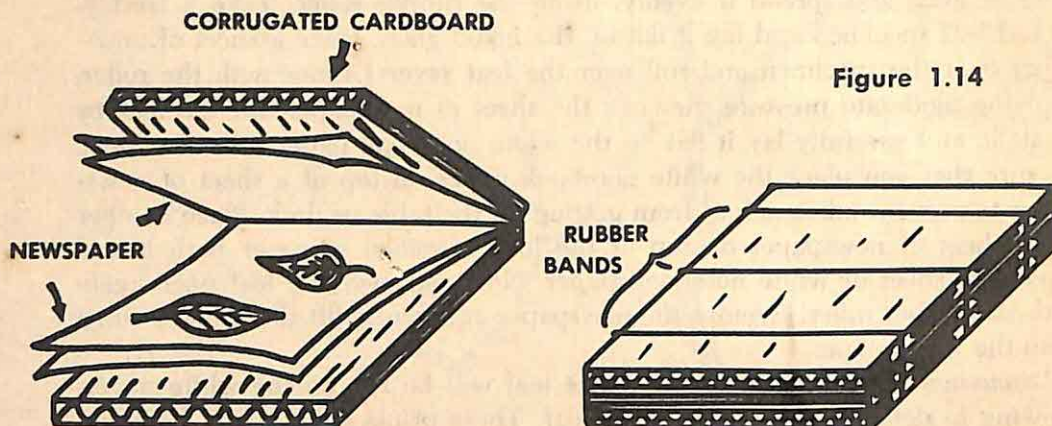


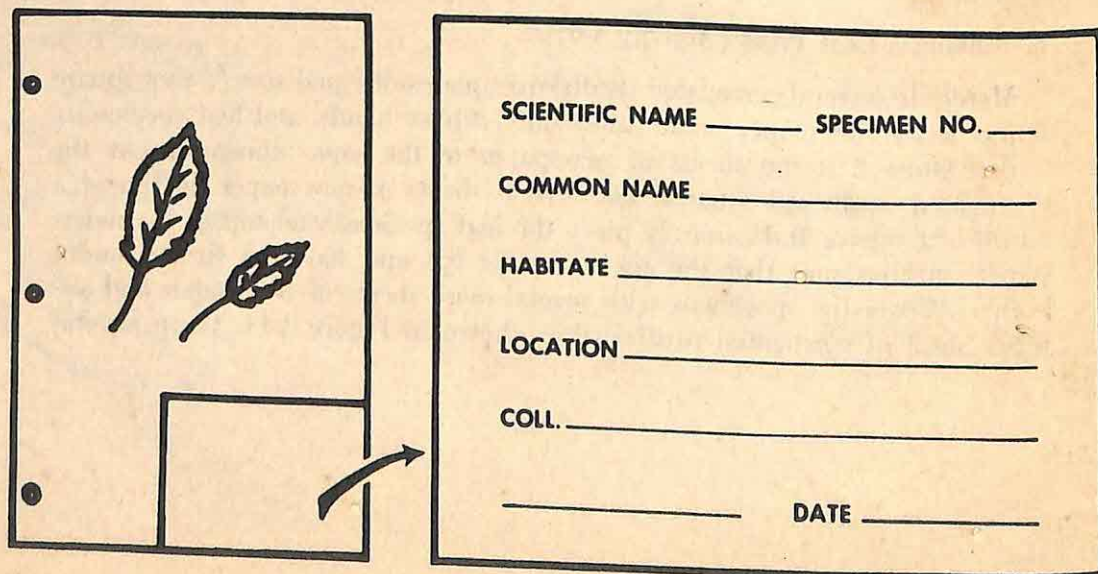
Figure 1.14

6. Making an Herbarium (Activity 4-6)

Materials: Plain white notebook paper, 3 by 5 inch plain cards, and an adhesive.

Procedure: After the leaf specimens are well pressed and dried, they will be ready for mounting in an herbarium. Mount the specimens on the white notebook paper with glue, paste, or cellophane tape. The usual procedure is to mount specimens of the same kind on the same sheet of paper, leaving the lower righthand corner for the data card as shown in Figure 1.15. The 3 by 5 inch data card should have the following information on it: (a) the scientific name of the specimen, (b) the common name, (c) habitat, (d) location where found, (e) collector's name, (f) specimen number, and (g) date collected.

Figure 1.15



Discussion: A collection of pages can be put together in a folder to form a collection of common plants or trees found on the school grounds or in the vicinity.

F. STUDYING WEED SEEDS

1. Introduction to Counting by Estimation (Demonstration 4-6)

Materials: Paper play money.

Procedure: Teacher with play money in hand begins counting one bill at a time, one every second.

"If you were to sit down at a table with a million dollars in one dollar bills and to begin counting the bills at a rate of one every second for twenty-four hours a day without stopping, how long would it take you to count one million dollars?" (Have the children work at their desks while the teacher works at the chalkboard.) "If we multiply 60 minutes by 60 seconds per minute, the result would be 3,600 seconds per hour. If we multiply 3,600 seconds by 24 hours per day, we would find that 86,400 dollar bills could be counted in one day. If we divide one million dollars by 86,400 dollars per day, we should end up with a good estimate of the number of days it would take to count one million dollars—one every second. It would take you about twelve days to complete the job. Of course, staying awake for twelve days straight would be an impossible task for anyone to perform. A man working eight hours a day without a break for lunch could only count 28,800 dollar bills at this rate.

"For this reason man has invented machines to do his counting for him. Before he had machines, however, he had to invent ways of counting large numbers of objects with greater speed. In the world of finance and banking man invented the 5, 10, 20, 50, 100, and 1000 dollar bills. This made the everyday task of counting money much easier.

"This invention is fine for bankers, but scientists rarely find things in nature that come in convenient numbers. They must find other methods of counting. Let us find out how they accomplish the counting of large groups of objects."

2. Counting by Estimation (Activity 4-6)

Materials: A single common weed plant and balance scale.

Procedure: Remove all the seeds from a single common weed plant and place them on a sheet of paper, spreading them out in a single layer. Those who live in an area where the Pigweed (*Amaranthus retroflexus*) grows will find this plant to be an excellent one to use. Its seeds number in the thousands and are easy to strip from the plant. Count out one hundred seeds and place them in a pile to the side. It will take several minutes to count out one hundred seeds. It would take several hours to count each one of the many thousands of seeds in the large pile. How can we speed up the counting of the large pile of seeds? This can be accomplished by placing the seeds in equal piles of approximately 100 seeds each. Piles of 500 seeds would even be quicker.

Another method of counting would be to place a pile of 500 or 1,000 seeds in one pan of a balance scale and then add seeds to the other pan until the two balance. A balance scale can often be borrowed from a high school chemistry teacher. If none is available, the home-made balance scale shown in Figure 1.16 can be constructed by using a board balanced on a fulcrum and a piece of clay for a balance weight.

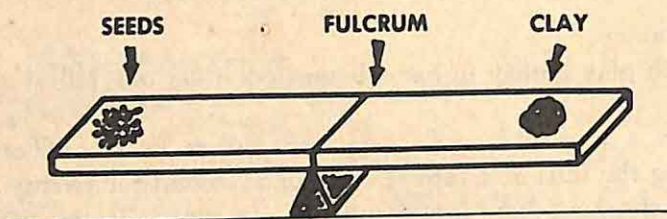


Figure 1.16

Discussion: The large pile of seeds can now be quickly counted by *estimating*. Estimation is a common method of counting used by scientists in their research when dealing with large numbers of objects. Surprisingly accurate results can be obtained by this method.

The accuracy of this method can be proved very easily. Have a group of children count the number of seeds in a large pile by using the method of estimating described above. Have the children record the results. Have another group of children then count the same pile of seeds one at a time. Compare the results—both the number of seeds counted and the time it took each group to count the seeds.

When dealing with large numbers, the accuracy of the measurement depends on three things: the measurer, the tools used in making the measurement, and the things you are measuring. When dealing with the counting of weed seeds, which could number in the millions, it is not necessary to be accurate to the nearest single seed, the nearest one hundred seeds, or even the nearest thousand seeds. In dealing with our single weed plant, which could have five thousand seeds, an estimate with an accuracy to the nearest one hundred seeds or even five hundred seeds can be considered to be accurate. This concept will be brought out even more vividly in the next demonstration, which deals with numbers in the millions.

3. Counting by Estimating and Sampling (Activity 5-6)

Materials: A single common weed plant and a sheet of paper marked off in small squares of equal size.

Procedure: Remove all the seeds from a single common weed plant and place them on the sheet of paper marked off in equal squares, spreading them out with great care in a single even layer. Count the number of seeds in a single square and record this number. If all the remaining squares have a single layer of seeds spread evenly over them, then theoretically each should contain approximately the same number of seeds as the square just counted.

The remaining task is a simple one. Count the number of squares covered by the single layer of seeds and multiply by the number of seeds counted in a single square. The question which will arise at this point will undoubtedly be, "How do we know all the squares had the same number of seeds covering them?" The answer is simple: "We don't know." We are assuming the number of seeds in the other squares to be very close to the number in the one we counted. We can, however, make our estimate more accurate by taking more *sample counts* of the seeds in other squares. Make two or three counts of other squares and take the average of all the counts. Let's pretend you made three sample counts of 100, 115 and 85. These figures would average out to be 100 seeds per square. The accuracy may not be as good as this hypothetical case, but it will be very close if the seeds are spread out carefully and evenly in a single layer. We have used two methods of counting, *estimating* and *sampling*.

The experience of working with estimating and sampling can be extended to a study of the number of weed seeds in a plot of ground on or near the school grounds, which could easily number in the millions.

It would be a difficult task to gather all the weed plants and stack them in a large pile and estimate how many piles of one hundred plants there were in the large pile. We can, however, divide the plot of land into many small plots of equal size and count the number of plants of the weed in which you are interested in one small plot of land. Now all we have to do is multiply the number of plants in the small plot by the total number of plots in the entire field. To find the number of seeds in the entire field, multiply the number of plants in the field by the number of seeds produced by one plant.

We can make our estimate more accurate by taking more *sample counts* of more of the small plots of land. We find that some plots will have more plants than others. If we take the average of these plots, we will get a better and more accurate count of the *average number* of plants in each small plot. With this new figure we can multiply the average number of plants in each small plot by the number of plots in the field. Now multiply the total number of plants by the average number of seeds produced by a single plant to obtain the total number of seeds produced by a single species of plant in the large field.

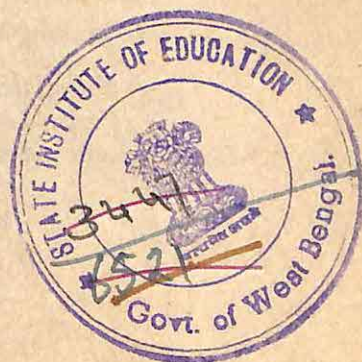
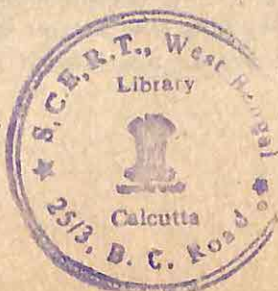
Discussion: The children will have had actual experience in working with two methods of counting used by research scientists, *estimating* and *sampling*. Actually they have been estimating and sampling for several years while performing division problems in their arithmetic classes. The children should also emerge from this experience with a realization of why weeds are so successful in surviving the destructive efforts of man. The answer lies partially in the number of seeds a single plant can produce.

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S.C.E.R.T., West Bengal

Date 7-1-87

Acc. No. 3659



II

Living Things—Animals

Paralleling the interest of elementary school children in plants is their interest in animals.

Like plants, animals are readily available for study. They can be found in many forms and sizes at home, at school, and out of doors.

Of great interest to elementary school children studying animals are the life cycle of animals, where they live and why they live where they do, how they survive seasonal changes, how they defend themselves, what they eat, how they gather their food, and how they can be identified.

Household pets and insects and their relatives (such as spiders, millipedes and centipedes) can easily be captured and studied at close range and in great detail. Because of the availability of insects for study, a substantial number of demonstrations and activities in Chapter II are devoted to the study of insects. This chapter, however, does provide many activities for studying other animals as well, such as amphibians, reptiles, mammals, fish, and birds.

For teachers having students who are highly motivated to study animals, Chapter II provides some advanced activities for the study of animals, such as collecting study skins, collecting mammal skulls, and the qualitative study of animal scats (droppings) to determine the diet of various local animals.

A. STUDYING INSECTS

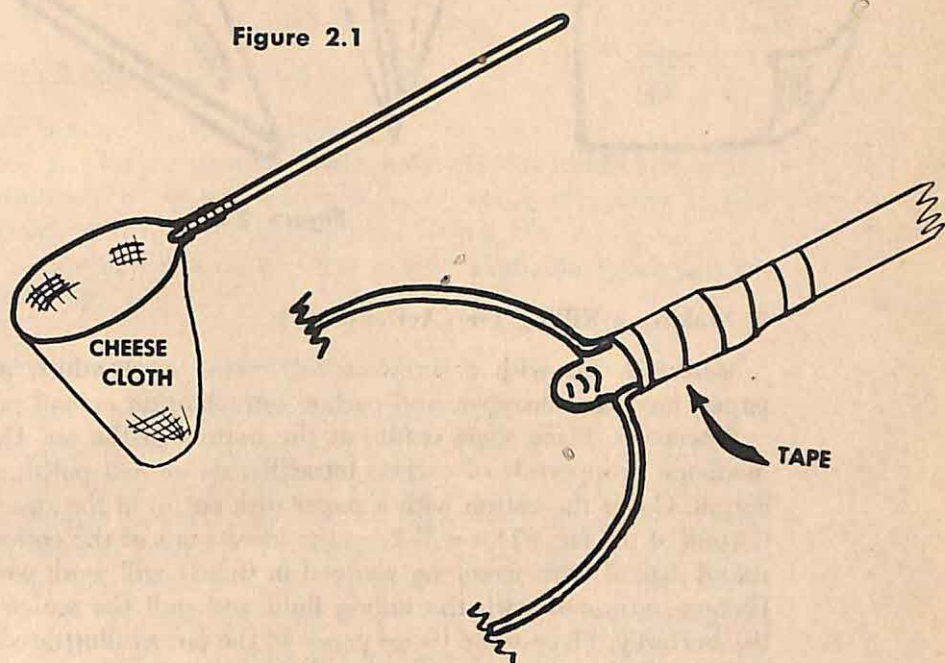
1. Making an Insect Net (Activity K-6)

Materials: Wire coat hanger, old broom handle, cheese cloth, and tape.

Procedure: Bend the wire coat hanger into a loop and attach it to the broom handle as shown in Figure 2.1. Obtain a cheese cloth bag from your local

butcher shop (meat packers cover the hinds of beef and pork with cheese cloth for shipping). Cheese cloths can also be purchased from the local five and dime store and cut and sewn into a sack to meet your own specifications. When washed, these cloths make fine bags for insect nets. Sew the open end of the bag to the wire loop.

Figure 2.1



Discussion: This arrangement will make an efficient net for collecting flying insects. Flying insects can be captured either in flight or as they come to rest on bushes, trees, or on the ground.

2. Making a Water Insect Net

Materials: Wire vegetable strainer, wire screening, broom handle, string, and tape.

Procedure: Cut a piece of wire screening into a square of the size you desire. Bend the screen into a funnel shape by drawing the corners together toward the center and overlapping each side an inch or two. Using a pair of scissors, trim the open end so that it is round and neat as shown in Figure 2.2. Attach the wire net to a broom handle, using flat head roofing nails or heavy duty staples.

Another way to make a water insect net is to tape a fine wire kitchen strainer to the end of a broom handle.

Discussion: Both types of strainers can be used to capture insects or other pond life several feet from the edge of a pond. Just dip the net in the water near the water insect and pull it up in a sweeping motion.

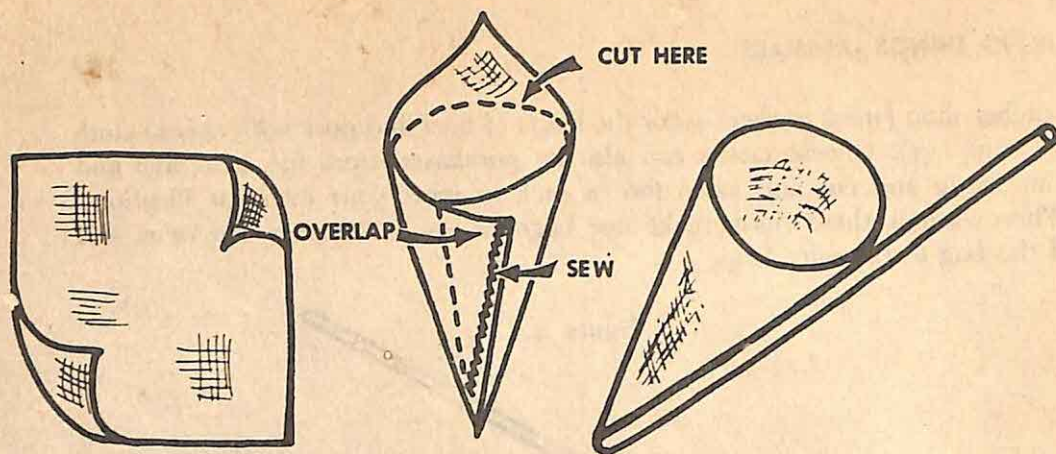


Figure 2.2

3. Making a Killing Jar (Activity 4-6)

Materials: Jar with a screw-on lid, cotton or sawdust, paper disk, tissue paper, medicine dropper, and carbon tetrachloride or nail polish remover.

Procedure: Place some cotton at the bottom of the jar. Deposit about two medicine dropperfuls of carbon tetrachloride or nail polish remover onto the cotton. Cover the cotton with a paper disk cut to fit the size and shape of the bottom of the jar. (This will keep the insects out of the cotton or sawdust.) A round disk of wire screening wedged in tightly will work well too. It will not become saturated with the killing fluid and pull the scales off the wings of the butterfly. Place some tissue paper in the jar, as illustrated in Figure 2.3, to prevent the insects from battering their wings against the sides of the jar.

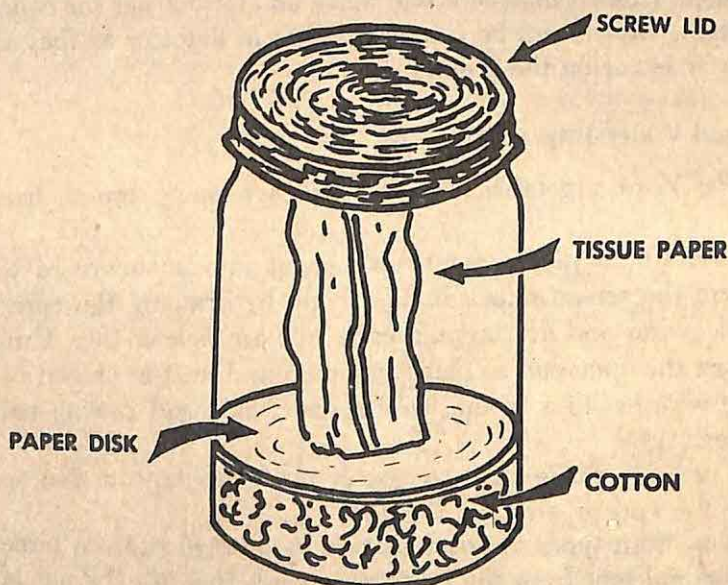


Figure 2.3

Discussion: The carbon tetrachloride will kill the insects in a few minutes and leave them in a relaxed state. As a *safety precaution*, do not leave the jar of carbon tetrachloride or the kill jar open for more than a few seconds indoors. Remember that carbon tetrachloride is poisonous and death can result from overexposure to it. However, if used properly and as directed, it will not cause any harm.

4. Catching Insects at Night (Activity K-6)

Materials: Small electric lamp and kill jar.

Procedure: Place an electric lamp outdoors on a chair or table and switch on the light. Within a few minutes many different kinds of insects will be attracted to the light and can easily be captured with a kill jar.

Discussion: The captured insects provide readily available specimens for collecting and mounting.

5. Making a Spreading Board (Activity 4-6)

Materials: Sheet of corrugated cardboard, straight pins, and glue.

Procedure: The size of your spreading board will depend on the size of the insects you intend to mount. Large winged insects require a wider spreading board than small winged insects. Nevertheless, here is a suggested size for general use. Cut a sheet of corrugated cardboard 14 inches by 8 inches. Draw some lines across the cardboard 3 inches and $3\frac{3}{4}$ inches from each end as shown in Figure 2.4 (a). This will give you two inclined planes slanted toward the center of the board. Space the ends of the inclined planes about $\frac{1}{2}$ inch from each other to form a channel in the center of the spreading board. The depth of the channel between the two inclined planes can be adjusted by adding strips of cardboard under each end along the channel. Glue and pin the inclined planes to the base at the proper distance and height desired.

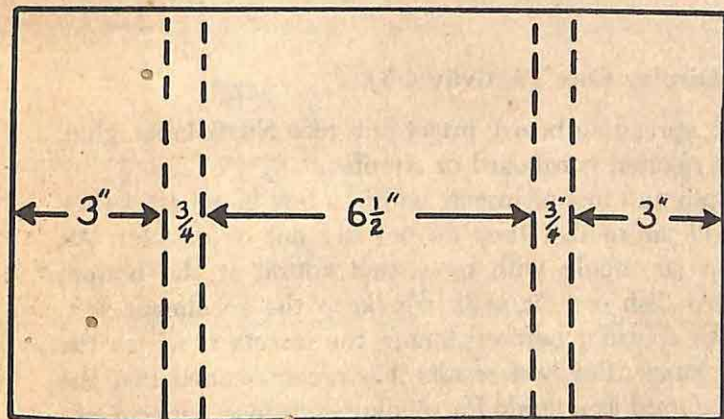
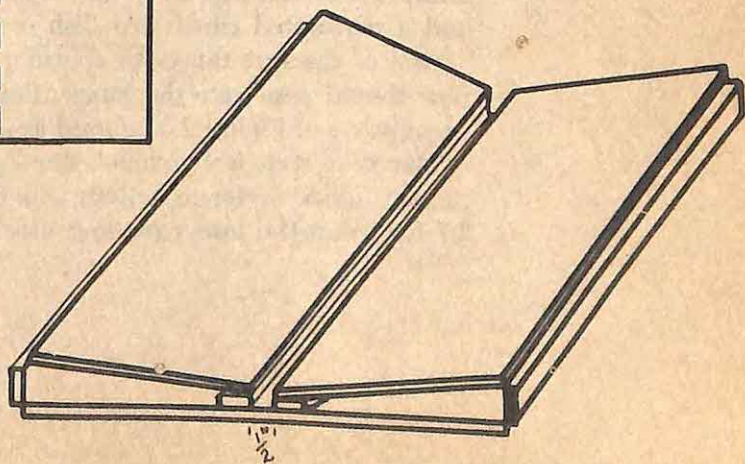


Figure 2.4



Discussion: You now have a spreading board for spreading and drying butterflies, moths, and other flying insects.

6. Making a Pinning Block (Activity 4-6)

Materials: Block of styrofoam plastic, block of balsa wood, or modeling clay.

Procedure: Cut a block of styrofoam plastic, balsa, or modeling clay to the dimensions suggested in Figure 2.5. When using "Size No. 2" insect pins, each step on your pinning block should measure $\frac{1}{4}$ inch. If you are using regular straight pins, each step will have to be lower. Use your own judgment to fit the specific situation.

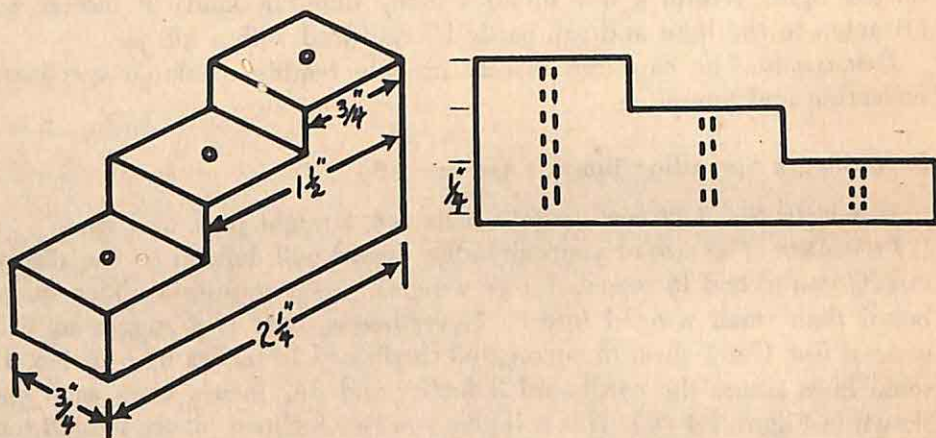


Figure 2.5

Discussion: The distance of the insect from the head of the pin and from the labels can be made uniform in the display box by inserting the pins in the holes at the steps desired. This will be discussed further in the next activity (number 7) of this chapter.

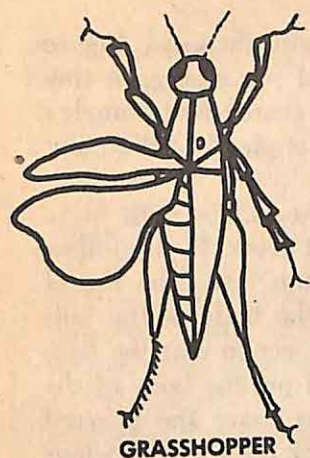
7. Mounting Insects in a Display Case (Activity 4-6)

Materials: Pinning block, spreading board, insect pins Size No. 2, label, glue, cigar box, and sheet of corrugated cardboard or styrofoam.

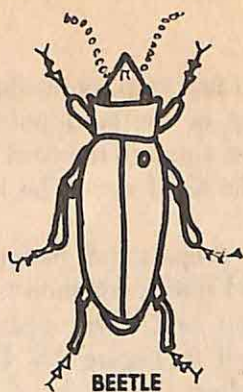
Procedure: It is best to pin and mount insects within a few hours after they have been killed in the kill jar so that they do not dry out or discolor. An easily constructed relaxing jar, made with moistened cotton at the bottom and a perforated cardboard dish over it, will help keep the specimens soft.

One of the first things to consider before pinning the insects is where the pins should penetrate the insect. For best results it is recommended that the suggestions in Figure 2.6 be used as a guide for pinning your insect specimens.

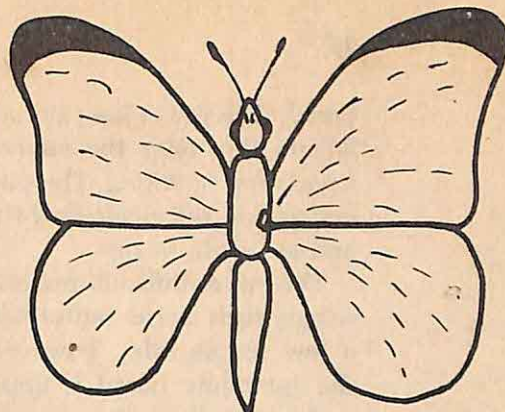
The next step is to mount the insects, using insect pins, labels, and the pinning block (refer to activity No. 6). Follow the steps illustrated in Figure 2.7 for using the insect pinning block.



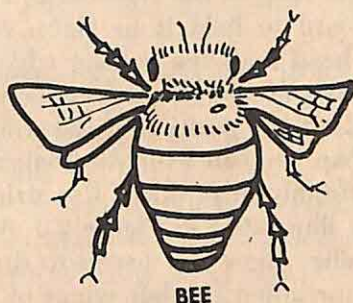
GRASSHOPPER



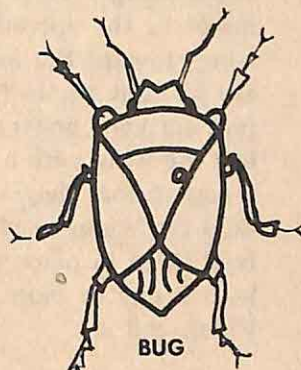
BEETLE



BUTTERFLY



BEE



BUG

Figure 2.6

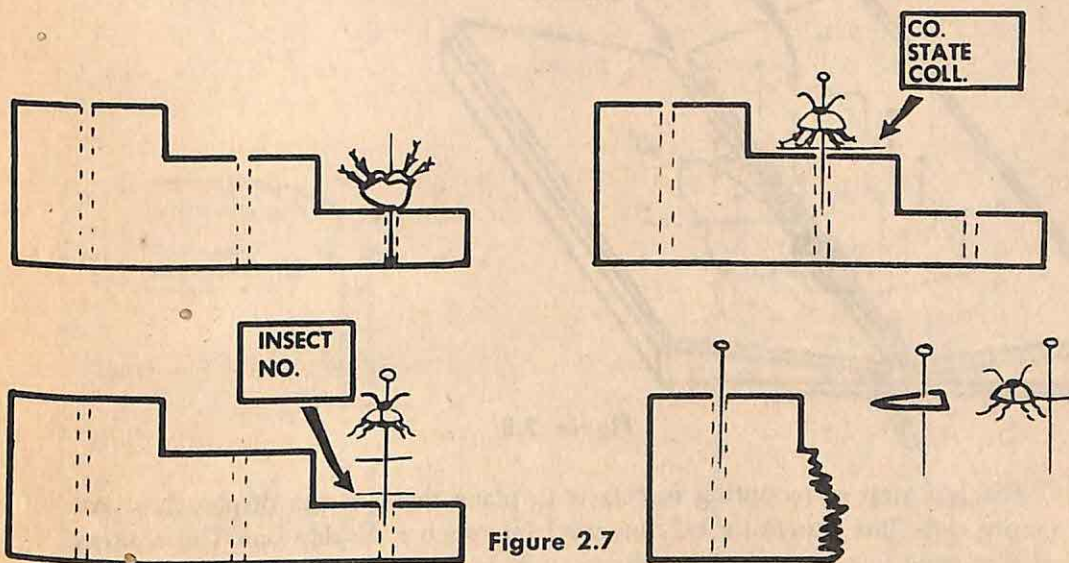


Figure 2.7

Figure 2.7(a) illustrates the adjustment of the height of the insect on the pin by inverting the head of the pin in the hole on step one of the pinning block. Figure 2.7(b) illustrates the adjustment of the height of the *location data label*. The pin is inserted on the second step, point down, with the label. Figure 2.7(c) illustrates the adjustment of the *insect no. label*, which is op-

tional. The pin is inserted on the first step, point down, with the label. Figure 2.7(d) illustrates the adjustment of the card point used for gluing on tiny insects for mounting. The pin goes through the card point (cardboard triangle) and is inserted point down in the third step. The insect is glued to the point and set aside to dry.

The most difficult insects to prepare for mounting are those with large wings, such as the butterflies and moths common to most areas. If you follow a few simple rules, however, you can be successful in this task. The use of the spreading board is illustrated in Figure 2.8. Place the body of the butterfly or moth in the channel, adjust the height of the insect so that the base of the wing is level with the rims of the sideboards, and pin the body of the insect to the spreading board to hold it in place. Next move the forward wings toward the insect's head until the trailing edges of the forward wings are at right angles to the axis of the channel as shown in Figure 2.8. Use a pin, *not* your fingers, to adjust the position of the wings. You can better control the wing with a pin than you can with your fingers. Next adjust the back wings so that they are uniformly in position. Use strips of paper and pins to hold the wings in place as illustrated in Figure 2.8. Adjust the antennae and hold them in place with pins. Allow the insects to dry in this position for at least a day or more. For spreading the left wings of a grasshopper, refer to Figure 2.6.

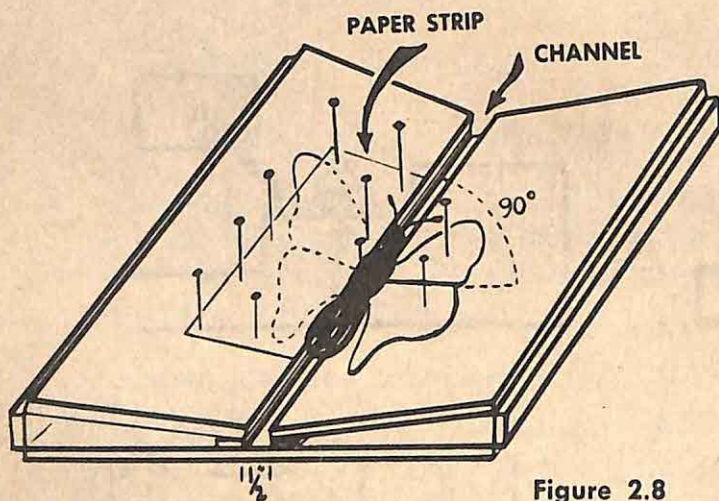


Figure 2.8

The last step in mounting insects is to place them in the display box. An empty cigar box can easily be converted into such a display box. Cut a sheet of corrugated cardboard or styrofoam to fit in the bottom of the box. This is used to hold the pins in place. Next, arrange the insects in neat rows with the labels and insects all facing in the same direction. The usual procedure is to arrange the specimens in rows according to their phylogenetic order.

Discussion: The greatest expense in making the insect collection is time and ten cents for insect pins. It should also be noted here that, in order to

preserve the specimens for a long time, it is a good idea to place some moth balls or a small sack of moth crystals in the display box to protect it from museum beetles (dermestids), which may lay their eggs on the specimens. If this does happen, the larvae of this beetle will feed on the collection and destroy it.

8. Making a Wire Screen Insect Cage (Activity K-6)

Materials: Wire screening and coffee can with lid.

Procedure: Roll some wire screening into a cylinder with the same inner diameter as a coffee can, keeping about a one inch overlap. Insert one end of the wire cylinder into the coffee can and use the coffee can cover to close off the other end as illustrated in Figure 2.9.

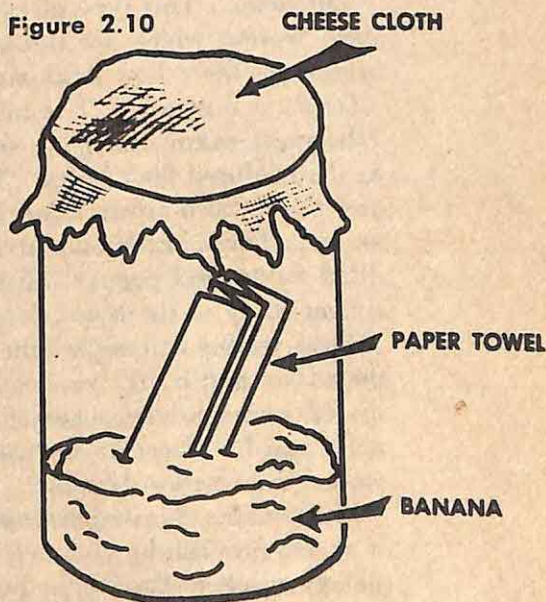
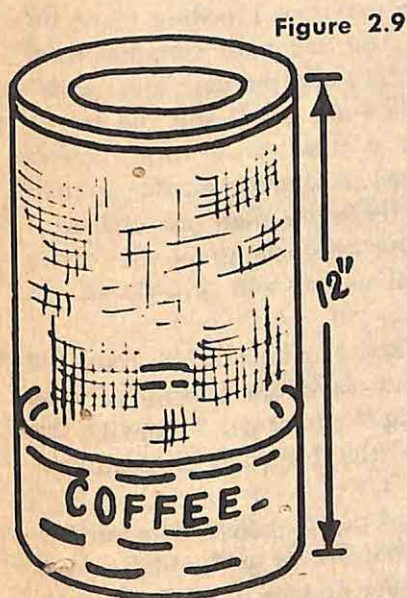
Discussion: You now have a wire cage to hold many different kinds of live insects for study. The height of the cage is up to you. However, it is suggested that twelve inches or less will make a very efficient cage which is easy to handle and does not become top heavy.

Insects which can be studied in a wire cage are grasshoppers, crickets, praying mantes, the larvae (caterpillar) of the monarch butterfly, the golden-rod gall fly, and the cocoons of many other insects.

9. Cages for Fruit Flies (Activity K-6)

Materials: Glass jar, cheese cloth, bananas or grapes, paper towel, and a rubber band.

Procedure: Crush or slice a banana or some grapes and place in the bottom of an uncovered glass jar. Place a length of paper toweling in the jar as illustrated in Figure 2.10.



Discussion: After a short while, several tiny fruit flies (*Drosophila melanogaster*) will have gathered in the jar, attracted by the banana or grape mixture. After a dozen or so flies have collected in the jar, cover the mouth with cheese cloth, securing it with a rubber band. Your chances of attracting male and female fruit flies in the same jar are good. They will probably mate or may have already done so, and the females will lay many of their eggs in the fruit. The larvae will pupate on the paper towel or on the side of the jar. You will be able to observe the life cycle of the animals in as short a time as eight days. A magnifying glass may help you to observe these tiny insects. If you have trouble attracting them to the jar during the day, focus a strong light on it at night. They are sensitive to light and are attracted to it. In addition to studying their life cycle, you can also use the fruit flies as food for aquarium animals.

10. Cages for Raising Meal Worms (Activity K-6)

Materials: Large glass jar, cheese cloth, oatmeal box, cigar box, milk carton, meal worm larvae, and bran flakes or oatmeal cereal.

Procedure: The construction of a cage for meal worms is similar to the construction of a cage for fruit flies (refer to activity 9 of this chapter). Any container which can be closed to prevent the escape of these insects and still provide them with air will be adequate. Some suggestions are a gallon glass jar with cheese cloth over the mouth, an oatmeal box with tiny holes punched in the lid, a milk carton covered with cheese cloth, or a cigar box with a lid. Bran flakes, oatmeal, or flour spread at the bottom of the cage will provide excellent food for these animals to thrive on. To provide moisture for the larvae, place a piece of wet sponge, paper, or a slice of potato or apple in the cage.

Discussion: This type of cage will provide an excellent breeding place for meal worms, which are the larvae of a beetle. The two most common meal worms are the yellow meal worm (*Tenebrio molitor*) and the dark meal worm (*Tenebrio obscurus*). The inch long adult beetles are black and the larvae (the meal worm itself) are brown or yellowish. A third meal worm, known as the confused flour beetle (*Tribolium confusum*), is a much smaller animal, and the reddish-brown adult beetle is only a little larger than one eighth of an inch. These beetle and larvae prefer to eat flour products, grain, chocolate, dried fruits, and pepper. All three of these meal worms will provide an excellent study of the life cycle of a beetle.

Meal worms can serve other purposes too. They can be used as food for the snakes and lizards you may be keeping in your classroom. If some of your students are studying mammals and are collecting skulls of dead animals, the skulls can be placed in the meal worm cage and the flesh will be neatly removed by the meal worms.

Meal worms can be purchased from a biological supply house. The address of such a firm can be obtained from the science coordinator or the high school biology teacher. You might be able to collect some from a local feed store. If you are diplomatic about asking the proprietor, you will not embarrass him.

11. Cages for Aphids (Activity 4-6)

Materials: Metal jar lid or a shallow dish or pan, one-hole rubber stopper, water, and stem of a plant hosting aphids.

Procedure: Insert the end of the plant stem hosting the aphids (plant lice) into the one-hole rubber stopper. Place the plant and stopper in the center of the jar lid, shallow dish, or pan. Pour some water into the lid to form a moat.

Discussion: The water in the moat prevents the wingless aphids from escaping from the plant stem. The water also serves to keep the plant stem fresh.

Aphids make interesting animals for study for many reasons. They can be found on many different kinds of plants, such as cotton, turnips, mustard, radishes, cabbage, rose bushes, goldenrod, aster, and many others. They have sucking parts which are used to remove the juices from the leaves, stems, or roots of a plant, destroying it.

Not all aphids are wingless; however, winged aphids are rare. It is also known that some generations of aphids are winged and others are not. Aphids usually give birth to living young, but during certain times of the year they will produce eggs. The children could easily observe the birth of the living young and the hatching of the eggs if time permitted.

Another interesting study which can be carried on with the captured aphids is the work of their predators, such as the larvae of the lady beetle (not bug), the larvae of the lacewing (aphis lion), and the syrphus fly larvae. All these insects lay their eggs among the aphid-infested plants. The eggs hatch and the larvae feed on and kill the aphids. When you cut a plant stem with aphids on it, look for worm-like larvae. They may be predators of the aphid, and your class could observe them in action.

12. Making an Ant Colony (Activity 4-6)

Materials: Large gallon jar with screw-on lid, sand, black construction paper, shallow pan of water, cardboard cylinder (mailing tube), two small sponges and some cheese cloth.

Procedure: A simple ant colony can be started in the classroom without buying window glass, sawing wood, or boring holes. Obtain a gallon mayonnaise or mustard jar from the school cafeteria and place a mailing tube in the center of the jar, holding it in position with your hand. Have a student pour some sifted sand inside the jar around the outside of the mailing tube. Fill the jar about half full, being sure to keep the mailing tube in the center of the jar. Find an ant hill and dig around it with a garden trowel or a shovel. Try to capture a group of ants with a queen ant among them. The queen ant will be the largest of the group and readily distinguishable from the rest. Place the soil with ants on a large sheet of paper and pour it into the remaining space in the mayonnaise jar. Cover the jar with a piece of cheese cloth and carry it back to the classroom. Fill up the shallow pan of water and place the

jar in the pan. Wet one small sponge with water and place it on top of the soil in the jar. Put some sugar water or honey water on the other sponge and place it on top of the soil too. You might add a few small bits of fat and some egg white from a hard boiled egg. Repeat this process every few days by adding a few drops of water and honey to the sponge. Cover the outside of the jar with black construction paper to make it dark inside.

Discussion: The ants will construct a colony in the jar with a network of tunnels and rooms, which can be observed by the children by removing the black construction paper. The children can study the life cycle of the ants and the effect of temperature change and light on the activity of the ants.

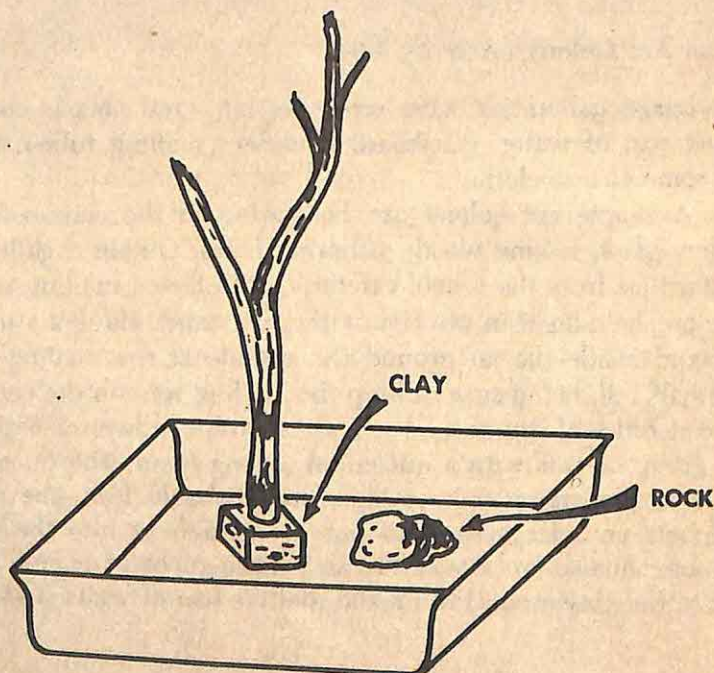
13. Keeping a Dragonfly Nymph in the Classroom (Activity K-6)

Materials: Shallow pan, block of modeling clay, a small branch, pond water, and a dragonfly nymph.

Procedure: Capture a dragonfly nymph, using the equipment mentioned in activity No. 2 of this chapter. Dragonfly nymphs can be found in ponds, lakes, and streams where they live for several months to a year. When you capture one, you will not know how long it will be before it will change into an adult. Place the captured nymph in a shallow pan of pond water with some rocks and pond weeds. Don't forget to add more pond water from time to time. Put a large rock or stick embedded in modeling clay in the pan of water (so that the nymph will have something to crawl out on when it sheds its skin at the time it becomes an adult) as illustrated in Figure 2.11. Feed the nymph raw hamburger, dead flies, meal worms, small fish, or fairy shrimp.

Discussion: The children may have a good opportunity to observe the nymph shed its skin (molt). They may also have the opportunity to observe

Figure 2.11



the nymph lift itself from the water to shed its skin and emerge as an adult dragonfly. Dragonflies are a good example of insects which do not develop through complete metamorphosis.

One precaution regarding dragonfly nymphs is that they are very predacious creatures and will eat almost anything, including small fish. Do not put them in an aquarium with fish you intend to keep.

14. Collecting Cocoons for Classroom Observations (Activity K-6)

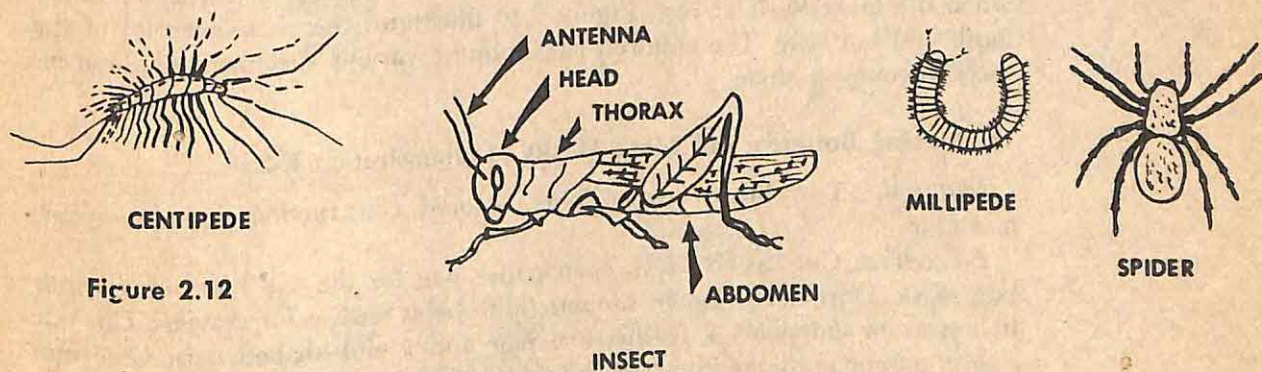
Materials: Insect cage and cocoons.

Procedure: Cocoons can be collected in the fall or spring. If they are collected in the fall, they can be kept in an insect cage in a cool place, on the window sill outside the classroom, or in a refrigerator. Adult moths will emerge from the cocoons in two to three months if brought into the warm classroom. Otherwise they will emerge in the spring when the weather becomes warm. Have the children check the necessary publication to identify their collection of cocoons.

Discussion: The children will have the opportunity to observe the adult moths emerge from the cocoons and can add them to their collection along with a specimen of the cocoon of each species found.

15. Identifying Insects and Their Relatives (Activity 4-6)

A good way to start a study of insect identification is to first make a distinction between insects and their "relatives," that is, animals which look like insects. Spiders, centipedes, and millipedes are some of these "relatives" often mistaken for insects. Figure 2.12 will help you to separate insects from spiders, centipedes, and millipedes.



Insects have six legs, two antennae, and three body parts—the head, thorax, and abdomen. Spiders have eight legs and two body parts—the head (cephalothorax) and abdomen. Centipedes have many body segments with one pair of legs attached to each segment; they have a total of more than eight legs. They have a pair of antennae and a pair of poison claws for paralyzing insects.

Millipedes have many body segments with *two pairs* of legs on each segment, except the first three segments which have only one pair; they have a total of more than eight legs. They have a pair of short antennae on their head but no poison claws.

16. Identifying Beetles and Bugs (Activity K-6)

Two of the most common orders of insects known to man are beetles and bugs, which are often thought of synonymously. Beetles, consisting of about 250,000 known species, make up about 35 per cent of all known insects. Bugs, consisting of about 30,000 known species, make up about 4 per cent of all the known insects. If you can identify these two orders of insects, you will be able to identify almost half of the insects you will find. Figure 2.13 will help you to identify beetles and bugs.

The best characteristic which can be used to separate beetles from bugs is the shape of the hard plate (scutellum) which covers and protects the flying wings. The *scutellum* of the bug forms a triangular outline, whereas the *scutellum* of the beetle meets in a straight line down the insect's back when the wings are at rest.

17. Identifying Butterflies and Moths (Demonstration 4-6)

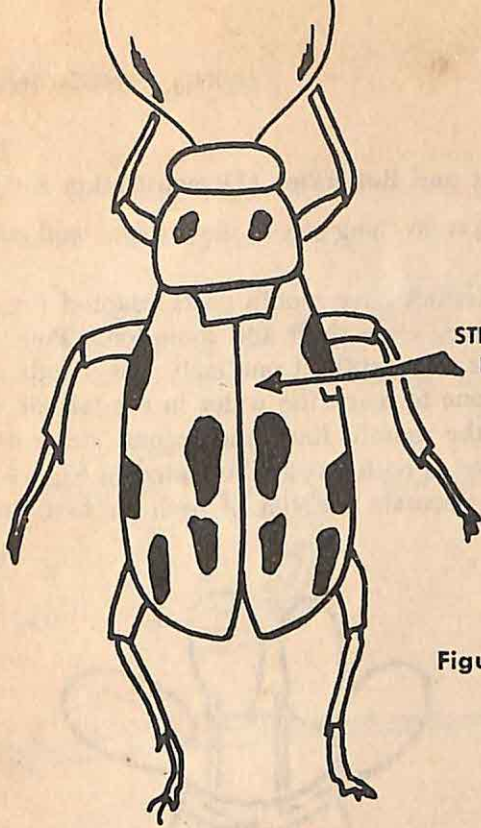
Another important order of insects is *Lepidoptera* under which falls the butterflies and moths. This order is second in size only to those of the beetles (Coleoptera), consisting of about 150,000 species. Moths and butterflies can easily be distinguished from each other by comparing several characteristics: the antennae, wings, and body shape. The body of the moth is stout, the antennae are feather-like, and the wings lie in a horizontal position when the moth is at rest. The body of the butterfly is slender as are the antennae which are club-shaped at the ends. The wings fold upright in a vertical position when the butterfly is at rest. Figure 2.14 illustrates the characteristics of the moth and butterfly. The children can examine various specimens of these insects to compare them.

18. Making Butterfly and Moth Masks (Demonstration K-3)

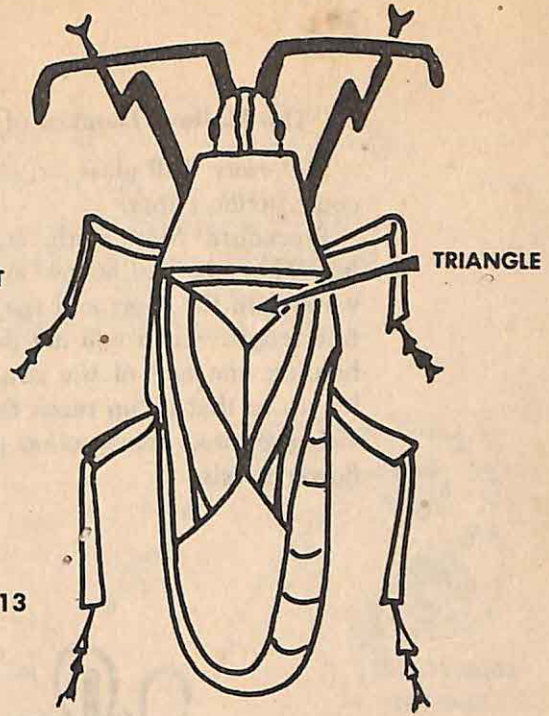
Materials: Two brown paper bags, colored construction paper, crayons, and glue.

Procedure: Cut two holes in each paper bag for the eye holes of a paper bug mask. Draw large circles around these holes with color crayons. Cut out two pairs of antennae—a feather-like pair and a club-shaped pair. Glue one pair of antennae to one insect mask and the other pair to the other insect mask as illustrated in Figure 2.15.

Discussion: These masks can be used to teach the children the difference between a moth and a butterfly by observing the antennae. This demonstration is quite effective in the lower grades. The children can make their own masks and test each other.



STRAIGHT
LINE



TRIANGLE

Figure 2.13

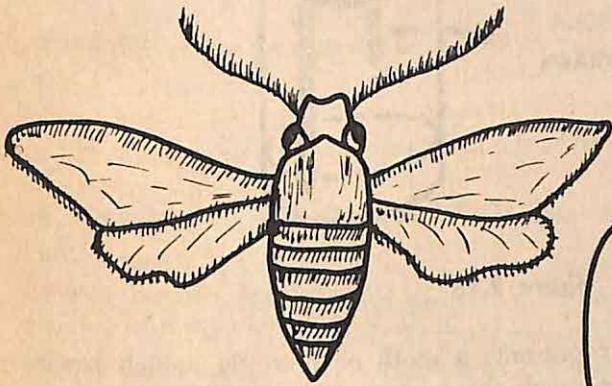


Figure 2.14

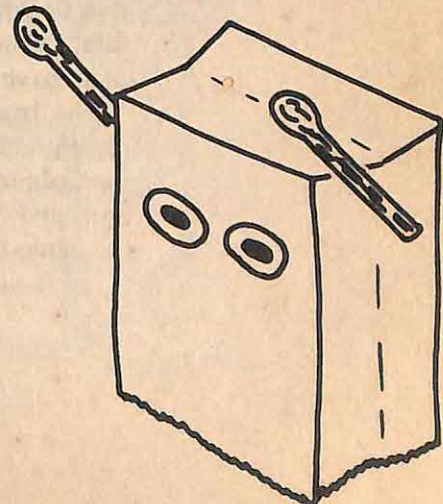
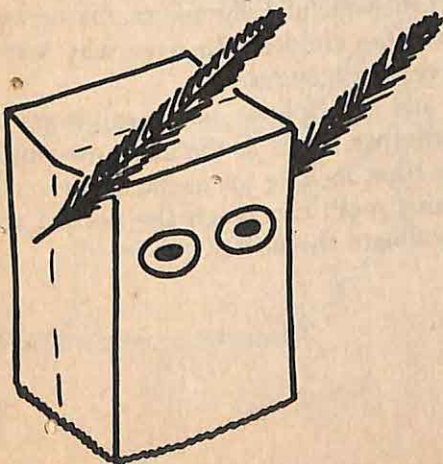
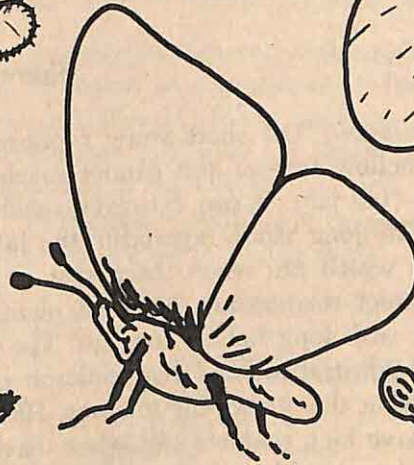
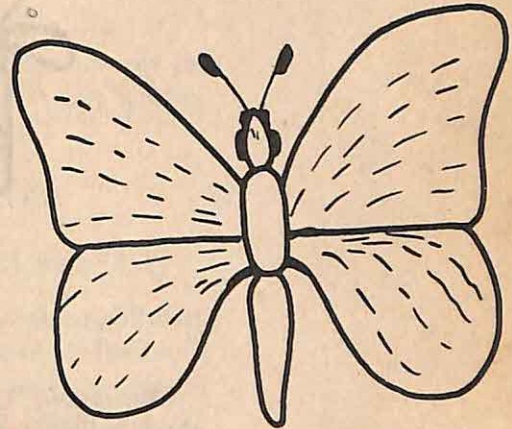


Figure 2.15

19. The Hollow Tongues of Moths and Butterflies (Demonstration K-6)

Materials: Tall glass jar, short glass jar, long straw, short straw, and colored construction paper.

Procedure: Most moths and butterflies have mouth parts adapted for sucking. They are like hollow soda straws, some short and some long. Pour some water into the short and the tall jar to a depth of one inch. Cut a soda straw to a length which will not permit one to reach the water in the tall jar while holding one end of the straw in the mouth. Keep the second straw at full length so that it can reach the water in both jars as illustrated in Figure 2.16. Using colored construction paper, decorate the rim of each jar to represent flower petals.

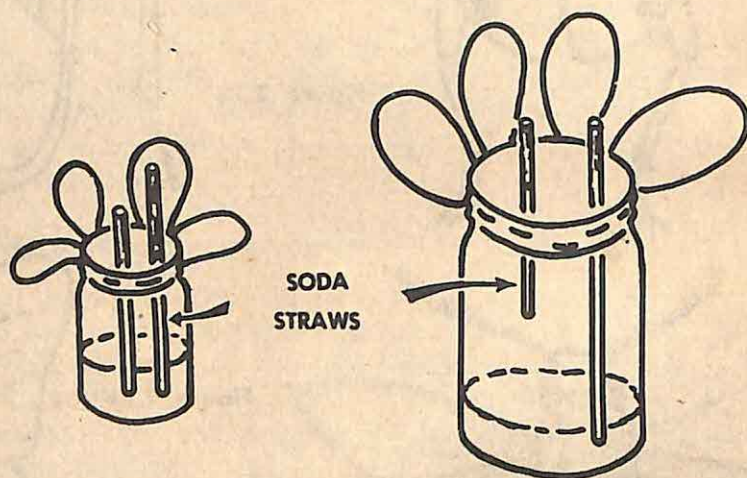


Figure 2.16

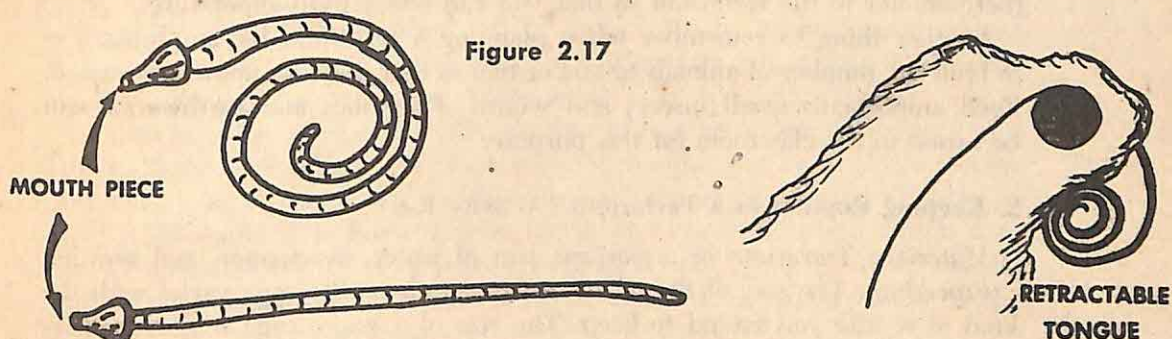
Discussion: The short straw represents a moth or butterfly, which has a short hollow tongue and cannot reach the nectar at the bottom of a deep flower (tall jar). It can, however, reach the nectar in a shallow flower (short jar). The long straw represents the hollow tongue of an insect with a long tongue which can reach the nectar in either shallow or deep flowers. There is a direct relationship between plants with long trumpet-like flowers and insects with long hollow tongues. The teacher can set up the equipment for this demonstration, and two children can pretend they are moths or butterflies, using the straws for tongues. Have the children discover why some insects have long tongues and others have short tongues.

The trumpet-like evening primrose and the Sphinx moth are closely associated with each other. The evening primrose opens in the early evening, and the Sphinx moth becomes active at this time, looking for nectar in flowers that are open. The long tongue of the Sphinx moth can reach the nectar, and at the same time the moth can help to pollinate the flower.

20. The Retractable Tongues of Moths and Butterflies (Demonstration K-6)

Materials: Roll-up party whistle and a moth or butterfly specimen.

Procedure: Find a moth or butterfly which has a retractable hollow tube-like tongue. Obtain a roll-up party whistle and compare the operation of this whistle with that of the tongue of the specimen you have found. The resemblance of the party whistle to the insect's tongue is illustrated in Figure 2.17.



Discussion: The children will be able to make a direct comparison of the operation of the retractable tongue of an insect with that of the party whistle.

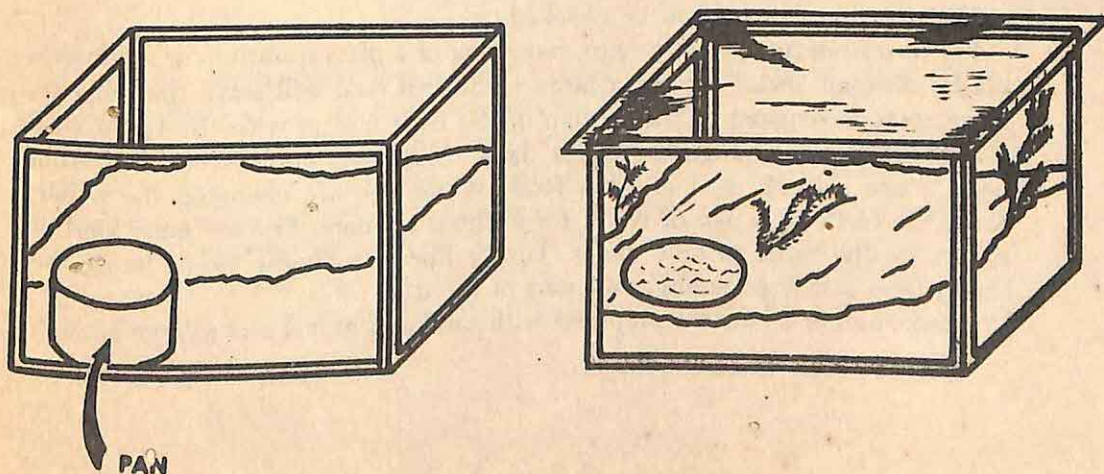
B. WORKING WITH TERRARIUMS AND ANIMALS

1. Keeping Frogs, Toads, and Salamanders in a Terrarium (Activity K-6)

Materials: Terrarium, plants, pan for water, thermometer, and amphibians.

Procedure: Construct and prepare a terrarium as suggested in Chapter I, Topic "B," "Working With Terrariums and Plants." Select some woodland plants and prepare your terrarium as illustrated in Figure 1.4, terrarium "A." Add a pool of water, made from a tin can or a shallow pan or dish, to the terrarium as illustrated in Figure 2.18. To capture amphibians in ponds, use a vegetable strainer or water insect net as illustrated in Figure 2.18.

Figure 2.18



Discussion: You now have a suitable habitat for most frogs, toads, or salamanders. Keep the terrarium covered to prevent the moisture from escaping. Remember that moisture is essential to the scaleless amphibians, as they lose body moisture quickly. *Do not* place the terrarium in the direct sunlight. Amphibians are cold blooded animals and are sensitive to high as well as low temperatures. A comfortable temperature for most amphibians is around 75° F. The temperature of a terrarium in the direct sunlight will reach 100° F. or more in a short time, which may prove fatal to the amphibians. Keep a thermometer in the terrarium so that you can check the temperature.

Another thing to remember when planning a terrarium for amphibians is to limit the number of animals to one or two so that they are not overcrowded. Feed amphibians small insects and worms. Fruit flies and earthworms can be raised in the classroom for this purpose.

2. Keeping Reptiles in a Terrarium (Activity K-6)

Materials: Terrarium or aquarium, pan of water, newspaper, and reptiles.

Procedure: The size of the terrarium used as a reptile cage varies with the kind of reptile you intend to keep. The size of a snake cage is governed by the size of the *snake*, but a snake cage can never be too large. A glass terrarium or aquarium with a screened cover is very suitable. Provide a few objects which the snake can climb onto or hide under and a small dish of water. Soil and plants are not necessary, as they are for amphibians. This is essentially a dry cage. For cleanliness line the bottom of the cage with newspaper and change it when necessary.

Most *lizards*, especially the desert variety, prefer dry cages or a sand filled desert-type terrarium provided with rocks or branches for climbing and hiding. A dish of water is also essential in the terrarium. Keep the cage in the sunlight so the lizards can sun themselves.

A *woodland lizard*, such as the favorite American "chameleon" (*anolis carolinensis*), prefers a woodland terrarium with ferns or leaves and a branch to climb on.

The American "chameleon" will not drink from a dish but will drink droplets of water sprinkled on the plants each day. A glass cover is excellent for maintaining the moisture in the terrarium, but it should not be kept on for any length of time when the terrarium is placed in the sunlight. Try to keep the temperature between 70° F. and 80° F. Keep a thermometer in the terrarium so that the temperature can be checked.

For *terrestrial turtles* a dry cage, consisting of a glass terrarium or aquarium, plastic dishpan, metal tub, or a large cardboard box, will serve the purpose. Place some newspaper at the bottom of the cage and provide the turtle with a dish for water. Change the paper daily to prevent unpleasant odors from body waste material and uneaten food. While you are changing the paper, bathe the turtle in a pan of water for an hour or more. Provide some kind of shelter for the turtle to hide under. Turtles like to sunbathe too so locate the cage where it will get sunlight for part of the day.

A terrarium or aquarium prepared with sand and gravel and a large enough

pan for a pool would make a fine home for an *aquatic turtle*. Place some large rocks in the pan of water and add sand and gravel flush with the pan of water to allow the turtle to crawl out of the water. Arrange the location of the cage so that it will receive some sunlight during the day. Change the water in the pan frequently to prevent unpleasant odors in the classroom.

Discussion: Keeping *snakes* in the room will provide the children with an opportunity to observe how and what they eat and how they shed their skins. Their food habits vary, depending upon the species. Some eat insects, fish, slugs, small mammals, and earthworms. Check a reference book to learn of your snake's favorite food. Much of the food eaten by snakes can be raised in the classroom. (Refer to Section "A" of this chapter.) It is best to keep the species of snakes that are native to the area.

Lizards provide a good study in comparing reptiles to amphibians. Superficially, lizards and salamanders look very much alike, but upon closer inspection many differences can be found. Many differences can be found between lizards and snakes too. For example, which one has eyelids and which does not? The food of the lizard consists mostly of insects, many of which can be raised in the classroom. Check a reference book for the food habits of the lizards native to your particular area.

Of the three reptiles discussed the *turtle* is the easiest to catch and the safest for children to handle. Their food habits can easily be studied. The food of most terrestrial turtles consists of plant life. They can be fed lettuce, apples, tomatoes, and other fleshy fruits. Some will eat worms, fungi, and raw hamburger. Aquatic turtles prefer small fish, insects, tadpoles, snails, and some aquatic plants. Again you are encouraged to check reference books for a more detailed description of the food habits of the turtles native to your area. Turtles make good subjects for studying the hibernation of animals. In colder climates turtles can be induced to hibernate by reducing the temperature in the cage. They will retract into their shells and refuse to eat for long periods of time. Placing them in the warm sunlight, under an electric lamp, or in a warm water bath will often revive them and induce them to eat.

Live reptiles, in general, provide many exciting activities for children in the elementary school classroom.

C. WORKING WITH AQUARIUMS

1. Keeping Fish in an Aquarium (Activity K-6)

Materials: Rectangular aquarium (5 to 10 gallons), glass cover, coarse gravel, rooted and non-rooted water plants, and water.

Procedure: (a) Clean the aquarium thoroughly with soap and water and rinse it several times to make sure that all dirt and soap has been removed. (b) Wash the coarse gravel thoroughly and fill the bottom of the tank to a depth of about two inches. (c) Hold a sheet of heavy paper or cardboard over the gravel and pour the water onto the paper as illustrated in Figure 2.19. This will prevent the gravel from being stirred up. Do not fill the

aquarium completely at this time. Clear pond water is preferred, but stream or well water will do if pond water is not readily available. If tap water is used, allow it to stand for about 48 hours before placing any plants in it. This standing period will allow the chlorine and other chemicals used in purification to escape. (d) Before planting, rinse all plants to remove dirt and algae from them. Clear a depression in the gravel and spread out the roots of two or three rooted water plants. Cover the roots thoroughly and bury part of the stem so that the plant will be held securely in place. Some popular rooted plants are *Vallisneria*, *Sagittaria*, and *Ludwigia*. Add two or three non-rooted water plants such as *Elodia*, *Cabomba*, and *Myriophyllum*. Anchor one end of the plant to the bottom with stones to hold it in place, allowing the upper part of the stem to float upright. Fill the tank with water to within one inch of the top of the tank. Plants serve several purposes in an aquarium. To some degree they replenish the oxygen in the water but not as much as many people think. They also serve to reduce the carbon dioxide content of the water, and they act as shelter for young fish. (e) Before stocking the tank, allow the water to clear. Stock the tank with fish that will live together and not prey upon each other. The general rule for stocking fish is *one inch of fish to one gallon of water*. This means you could stock 6 one-inch fish in a six gallon tank or 3 two-inch fish in the same tank. You may also add two snails for each gallon of water. The snails eat much of the algae which grow on the sides of the tank. (f) Place a glass cover over the top of the aquarium to reduce the rate of evaporation.

Discussion: You now have a well-balanced aquarium, which will remain in balance if given the proper care. One way to keep your aquarium in balance is to limit the number of *new plants* which are allowed to grow. Many of the water plants produce new plants from runners. The first sign of too many plants is the browning of the leaves of younger plants.

To reduce the amount of algae growth, darken the aquarium. The sides can be scraped with a single-edged razor blade and the dirt siphoned from the bottom with a rubber hose. A dip tube with a syringe bulb can be used to collect animal waste and uneaten food as illustrated in Figure 2.20.

Some *fish*, such as guppies, are quite prolific and will cause the aquarium to become overcrowded within a few months' time. Remove some before they get too large. The children could take them home for their own aquariums.

Figure 2.19

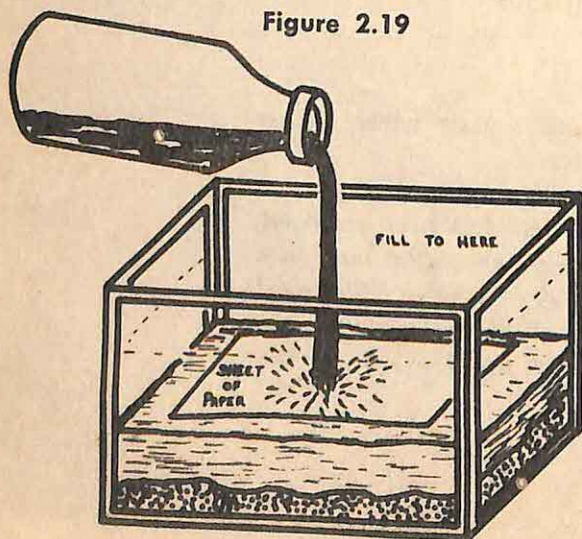
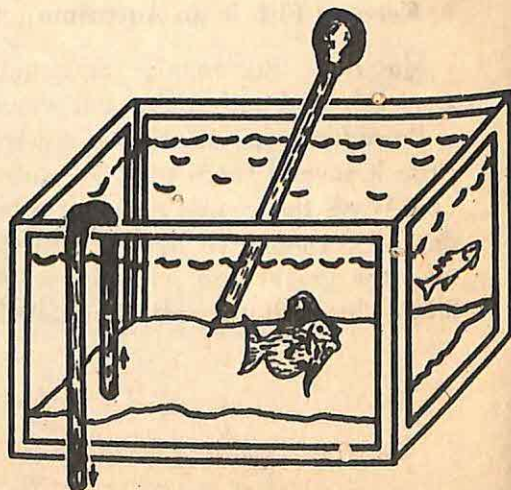


Figure 2.20



The *temperature* of the water is another important factor in maintaining the balance of the aquarium. Algae are more prolific in warm water than in cool. The best temperature for healthy aquarium fish is between 60° F. and 70° F. Check a reference book for any specific species of fish.

Proper *feeding* of the fish is important too. To reach a decision on *how much* to feed will take some experimentation. The generally accepted rule is to feed the fish only that amount of food which they can completely devour in about 15 minutes. The choice of food depends upon the species of fish. Again, check a reference book for details on the kinds of food to feed your fish.

If handling the fish is necessary, use a small dip net. Home-made dip nets can easily be made from the toe end of a white cotton sock sewn on to a wire coat hanger in much the same manner as the insect net illustrated in Figure 2.1.

2. Keeping Water-Borne Amphibians in an Aquarium (Activity K-6)

Materials: Aquarium and adult aquatic newt.

Procedure: Prepare an aquarium as you would for fish. Capture two or three adult newts common to the area. To obtain more information about the identification and life history of these amphibians, look in a reference book under the family name *Salamandridae*. This family has two genera, *Notophthalmus* and *Taricha*. Six species will be found, three in each genera. Their natural food habits consist of eating worms, leeches, crustaceans, insects, frog eggs, and young amphibians. It is imperative, then, that frog eggs, tadpoles, and other young amphibians not be raised in the same tank with the newts. In captivity they will eat cut earthworms, raw hamburger, and the white of a hard-boiled egg. When newts are first placed in captivity, they should be food-trained. At feeding time, remove them from the tank and place them in a small container of water from the aquarium. Feed them bits of food with forceps or eyebrow tweezers. Continue this method of feeding until they become conditioned to it. After awhile, they will come to the surface of the water for food at the sound of your fingers tapping on the tank. Feeding in this manner prevents contamination of the water. Fruit flies and earthworms can be raised in the classroom as food for these animals.

Discussion: The children can observe the feeding, mating, and egg laying habits of these animals and compare the breathing of newts (through gills) with that of land salamanders (with lungs). The growth and development of young newts can also be studied.

3. Using Jars and Shallow Pans as Aquariums (Activity K-6)

Materials: Shallow porcelain pan and several glass jars of various sizes.

Procedure: Shallow pans and glass jars make good temporary aquariums for conducting many exciting activities with aquatic animals. Shallow porcelain pans make excellent aquariums for raising salamander, frog, and toad eggs. The large surface area of water exposed to the air aids in replenishing the supply of oxygen in the water. It also permits rapid evaporation of the water

so that native pond water must be added from time to time. Native pond plants of the rootless variety should be added to this aquarium to act as a protective cover for the tadpole and salamander larvae.

Large gallon jars can also be used to raise salamander and frog eggs. They can be used to house mosquito eggs and larvae, too.

Discussion: The children will have the opportunity to observe and study a variety of aquatic animals in the temporary aquariums. Using pond water in the temporary aquariums will provide the young tadpoles with enough vegetable matter to sustain them until they are fully developed. Mosquito larvae raised in an aquarium can be used to feed the hungry salamander larvae. The children will soon realize the value of salamanders as destroyers of mosquitos. The value of other water insects as destroyers of mosquito larvae can be demonstrated by adding several dragonfly nymphs, Diving Beetle nymphs or Water Scavenger Beetle nymphs to the aquarium containing mosquito larvae. Do not introduce these insect nymphs at the same time, as they will attack each other.

4. Keeping Snails in an Aquarium (Activity 4-6)

Materials: Temporary jar aquarium, snails, pond water, and a magnifying glass.

Procedure: A temporary aquarium for studying aquatic snails can be made from empty jars. Place two or three aquatic snails in an aquarium filled with pond water. Care for the aquarium as described earlier in this chapter. It is not necessary to feed the snails, as they will feed on the algae which grow in the aquarium.

Discussion: The children can observe the snails laying their eggs on the sides of the aquarium. The eggs are laid in a jelly-like mass which adheres to the side of the aquarium. With the aid of a magnifying glass, the children can observe the hatching of the eggs and the development of the young. Some aquatic snails give birth to living young viviparous. Check reference books for these species.

D. KEEPING MAMMALS IN THE CLASSROOM

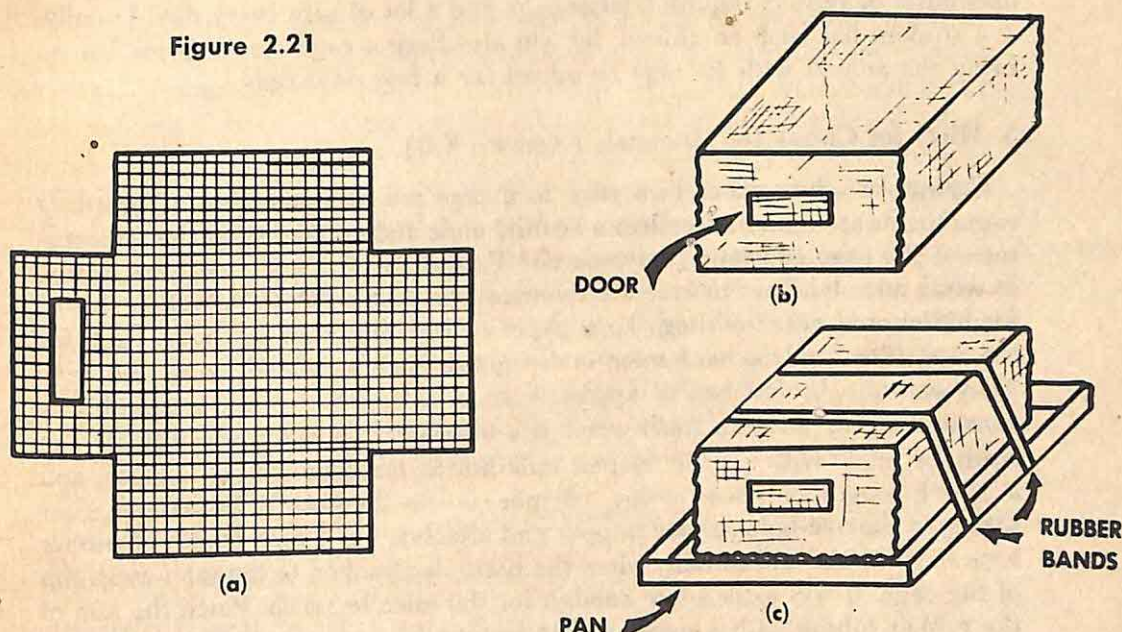
1. Cages for Small Mammals (Activity K-6)

Materials: Quarter inch wire mesh, wire paper clips or annunciator wire, tin snips, large inner tube rubber bands or string, cookie tin or shallow porcelain pan, and newspaper.

Procedure: A simple wire cage can be constructed from a single section of quarter inch wire mesh. The dimensions of the cage are up to you. You may want to first cut a pattern from newspaper before cutting the wire. Measure and cut the wire as illustrated in Figure 2.21(a). Bend the wire into a cage as illustrated in Figure 2.21(b). Fasten the sides with wire, looping it through the wire mesh and twisting the ends. "Hog nose" staples pinched together

with pliers also work well in fastening the sides together. Wire hinges can be made for the mesh wire door too. Place some newspaper in a metal cookie tin or shallow porcelain pan, which will serve as the floor to the cage. Stretch two inner tube rubber bands over the wire cage and try to hold them in place as illustrated in Figure 2.21(c). If the cage is too large for the rubber bands to stretch around, use some wire. Tie the string in a bow to facilitate easy removal when cleaning the cage.

Figure 2.21



Discussion: You now have a cage which can be used to house mice. The mice will also need a place to hide and a dish with water for them to drink. A small cardboard box with torn paper strips will serve as a good hiding and nesting place for the mice. To keep the cage clean and free from offensive odors, replace the newspaper at the bottom of the cage frequently. Clean the water dish and replenish daily.

Children in the fourth, fifth, and sixth grades have had good success constructing these cages themselves with some supervision by the teacher.

2. Cages for Larger Mammals (Activity K-6)

Materials: Quarter-inch wire mesh, large glass aquarium (15 gallons), and a metal watering tub or large homemade glass terrarium.

Procedure: For mammals larger than mice, such as rats and hamsters, a larger cage is required. A variety of equipment is available, such as a 15 gallon aquarium, a large homemade terrarium built to your specifications, or a large animal watering tube. A cover for these cages can easily be made from quarter-inch wire mesh stretched over a wooden frame designed to fit over the top of the cage.

Discussion: Like mice, rats and hamsters like a place in which to hide and nest. The floor of the cage should be covered with newspaper, paper excelsior, or sawdust. This bottom covering should be changed frequently to avoid unpleasant odors. A daily supply of clean fresh water is also essential for healthful living.

Keeping wild mammals other than mice in the classroom is recommended for short periods of time only. Wild animals such as squirrels, raccoons, opossums, or rabbits require a large cage and a lot of care every day. Usually, if a student has such an animal, he will also have a cage for it. Allow him to bring the animal with its cage to school for a few days only.

3. Hints for Caring for Mammals (Activity K-6)

Caring for white mice: Two mice to a cage are recommended. If breeding experiments are intended, collect a healthy male and female. Keep the temperature of the cage constant (between 68° F. and 72° F.) and free from drafts, as white mice tend not to breed in temperatures above 80° F. Provide a shelter for hiding and nest building. Torn paper or bits of cotton will serve well for the nest. The food of most mice is dry grains such as wheat, corn, and oats. They can also be fed bits of apples, lettuce, celery, and other vegetables. A constant supply of clean fresh water is a necessity. An automatic waterer can easily be made with a small $\frac{1}{2}$ pint milk bottle, one-hole rubber stopper, and a 4-inch length of glass tubing (6 mm. inside diameter). Insert the glass tubing in the one-hole rubber stopper and attach a 4 to 6 inch length of rubber hose to the other end so that, when the bottle is attached to the wire mesh top of the cage, it will extend low enough for the mice to reach. Pinch the end of the rubber tubing with a paper clip to restrict the opening so that the atmospheric pressure prevents the water from flowing out all at once. Adjust the pressure of the paper clip accordingly. As the animals drink the water, the tube will fill up again.

Caring for white rats: The cage should be larger than that used for mice. Two rats, male and female, are recommended for one cage. The care of the cage is essentially the same as that for mice. Keep them clean by changing the newspaper on the floor of the cage frequently. Do not place the cage in direct sunlight and avoid any drastic changes in temperature. Feeding rats is an easy task. They are indiscriminate eaters, omnivorous, and will eat table scraps of meat and vegetables. Leftovers from the noon meal at the school cafeteria will serve as a free source of food for your rats. Rats will need nesting material too and a secluded place to build their nest. Again you can use shredded newspaper for nest material and a shoe box for a nesting place.

Caring for hamsters: The cages used for housing a pair of hamsters must be made of metal, wire, or glass. These animals are rodents and have been known to destroy wooden cages with their gnawing. Hamsters are nocturnal animals and usually feed at night. It is a good idea, then, to feed them before leaving the classroom in the late afternoon rather than in the early morning before classes begin. This will prevent the food from spoiling before the hamsters get an opportunity to eat it. Their food consists of fresh fruits, fresh

vegetables, and the various grains. The care of the cage is essentially the same as for mice and rats.

General hints: (a) To handle white rats and mice, pick them up by the middle of the tail and place them in the palm of your other hand. Be gentle but firm, and do not move with quick jerky motions. (b) Remove the male animal from the cage just before the female is to give birth to her young or shortly thereafter. (c) Remove any sick, injured, or bleeding animals from the cage immediately and keep separate until they have recovered. (d) Wear gloves when handling newly acquired animals until they have become friendly with you. Remember that hamsters have sharp teeth. (e) These animals can be purchased from biological supply houses or obtained free from veterinarians, college research laboratories, or high school biology classes. Some of your own students may have them as pets at home. (f) Prepared food pellets can be purchased from local food stores. They are often referred to as "Laboratory Chow." They can be fed to mice, rats, guinea pigs, rabbits, and hamsters.

Contribution to the science program in the classroom: (a) Study the physical characteristics of mammals as compared to amphibians, reptiles and birds; (b) Study the reproduction and parental care of mammals; (c) Study the feeding habits of mammals; (d) Use mammals in nutrition experiments; (e) Teach the children the proper care of their own pets; (f) Note how the feeding habits of these animals can help or hinder man.

E. STUDYING BIRDS

1. Collecting Bird Nests (Activity K-6)

Materials: Several shoe boxes, bird field book.

Procedure: The best time to collect bird nests is in the late fall or winter, especially in the parts of the country where seasonal changes are obvious. By late fall, most birds have abandoned their nests. Bird nests can be found in trees, in bushes, in holes in trees, inside and outside of buildings, on the ground, and in holes in the ground. Find out by observation and from the many field books on birds what species are common to your locality. The field guide will also give a description of the nest for each bird. After collecting the nests, spray them with insect spray to kill the many kinds of insects which find a home in the nest material. This will eliminate a great number of insects which would otherwise be brought into your home or school. Store the nests in shoe boxes and place identifying labels on them.

Discussion: The children in your classroom will soon have a sizeable collection for studying the materials which are used in the construction of bird nests. These materials are often clues to the kind of bird that built the nest. The size and shape of the nest are also good clues to the kind of bird which built it. A study of the species of birds in the area can be made in this manner without ever actually observing the birds themselves.

2. Building Tin Can Bird Houses (Activity K-6)

Materials: Tin cans of various sizes, tape, nails, and wire or string

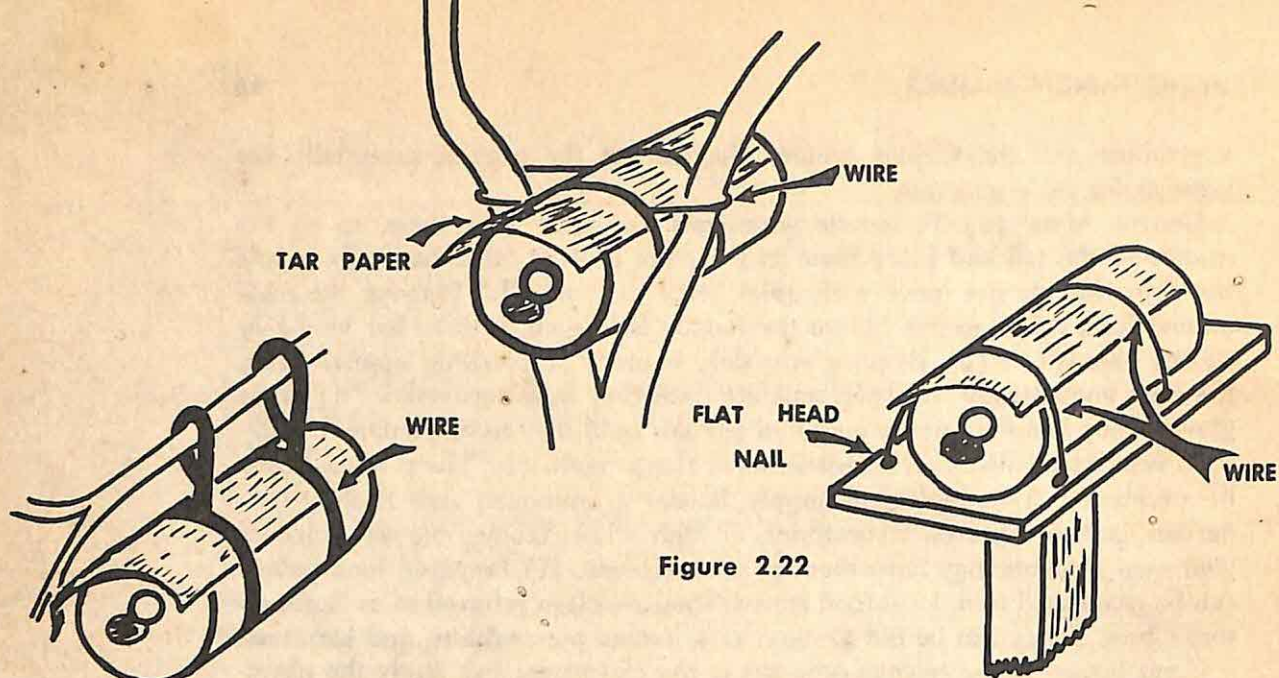


Figure 2.22

Procedure: Large juice cans, fruit cans, peanut butter cans, and mayonnaise cans from the school cafeteria can easily be made into bird houses. Cut a hole large enough for the bird to get through in the center of one end of a tin can.

A juice can which has not had the end cut out but was punctured for pouring out the liquid content will work well. Flatten the sharp edges of the hole, bending them inward with a pair of pliers. You may want to line the edges of the hole with black electrical tape if there are some sharp edges present. If the tin can has had the end cut out, cut a piece of pine board to fit the end. Your school custodian or shop teacher will be happy to assist you in this task. Cut a hole large enough for the bird to enter the house in the center of the board.

To mount a perch for the birds to land on, cut a one-fourth inch hole about one inch below the entrance and insert a one-fourth inch diameter dowl four inches long. The perch is necessary to aid some birds in crawling into the opening of the house. If the hole is cut in the metal end of the can, bend the cut out portion outward to serve as a perch as illustrated in Figure 2.22. Perforate the closed end of the can to allow for ventilation. To preserve the metal and make them less conspicuous, paint the house with a black enamel paint. Tin can bird houses are easy to mount in trees or on a post using wire and flat head nails as illustrated in Figure 2.22.

Discussion: With the bird houses completed and mounted, many observations can be made of the habits of birds. The children may have the opportunity to observe which partner, *male* or *female*, does the nest building. They may observe which partner feeds the young. The length of time it takes a species to build a nest and raise their young could be recorded. These and many other observations could be made. Children of fourth, fifth, and sixth grades have successfully built tin can bird houses with some supervision by the classroom teacher.

3. Building a Bird Feeding Station (Activity K-6)

Materials: Two pie tins, large tin can, wire coat hanger, and a block of wood.

Procedure: Assemble the above-mentioned materials as shown in the exploded view in Figure 2.23. The top pie tin provides a cover for the feed container, protecting it from rain water and snow. The bottom pie tin provides a tray for the bird feed and a shelf for the birds to perch on as they eat. The large tin can is the feed bin with an open top for easy filling. The bottom is closed and the holes on the sides allow the feed to flow into the feed tray. This type of feeder is often referred to as a *gravity feeder*. As the birds eat the feed, more flows out through the holes, forced by gravity. The wooden block at the bottom of the feeder prevents the wire from slipping out through the hole and provides a solid base for the pie tin to sit on.

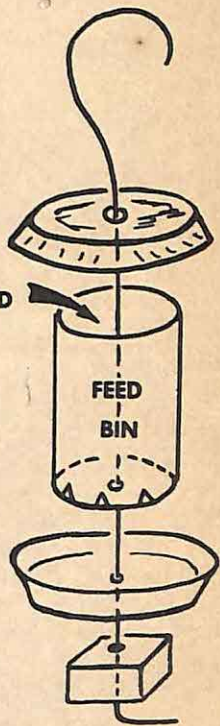
Figure 2.23 OPEN END

Discussion: This type of bird feeder can easily be hooked onto a branch of a tree or a rail fence near your school. Replenishing the feed bin is easily accomplished by unhooking the wire from the tree and lifting the top pie tin.

4. Collecting Dead Birds (Activity 4-6)

An interesting study of bird beaks and feet can be conducted with dead birds. Children are often bringing to school dead birds which they find on their way to school, along the side of the road, or in a field. Birds which have been dead for a day or so, especially in cold weather, will not have decayed enough to have a disagreeable odor. Freshly killed birds can easily be preserved for long periods of time if injected with a 10 per cent formalin solution using a 25 cc hypodermic syringe. Insert a number 20 needle into several different places in the body cavity, neck, head, and front edge of the wings and inject the formalin solution. Hospitals, clinics, and veterinary hospitals that use penicillin usually dispose of the syringe after one use. These institutions are quite willing to let you have them for your classroom projects. With a little encouragement your students will bring many specimens to class for study.

Discussion: With these bird specimens the children can compare the feeding habits of the various birds with the type of beaks and feet they have. A good example would be to compare the beak of a hawk or owl, which are primarily flesh eaters, with that of an English sparrow, which is a seed and insect eater. The children could compare the feet and claws of a hawk with the feet of a duck. Before starting a bird collection, formulate some rules for collecting specimens, such as that: (a) no one shoot or in any way destroy live birds; (b) the specimens be fresh, not badly decayed; (c) if the specimen is found when school is not in session, it be wrapped in a plastic bag and placed in a freezer or refrigerator to preserve it; (d) the student who brings the specimen to school be responsible for disposing of it after it has been studied.



F. FIELD ACTIVITIES FOR STUDYING ANIMALS

1. Live Traps for Collecting Small Mammals (Activity 4-6)

Materials: Mouse trap, board four inches wide and 12 inches long, wire, large inner tube rubber bands or wire, tin can, and $\frac{1}{4}$ inch wire mesh.

Procedure: Tack the mouse trap to the board as illustrated in Figure 2.24(a). Slide the open end of the tin can under the tripping mechanism of the trap and secure it in place with inner tube rubber bands or wire as illustrated in Figure 2.24(b). Cut a square of $\frac{1}{4}$ inch wire mesh to fit over the mouth of the tin can with a one inch overlap. Using wire, attach the wire mesh to the trap itself as illustrated in Figure 2.24(b).

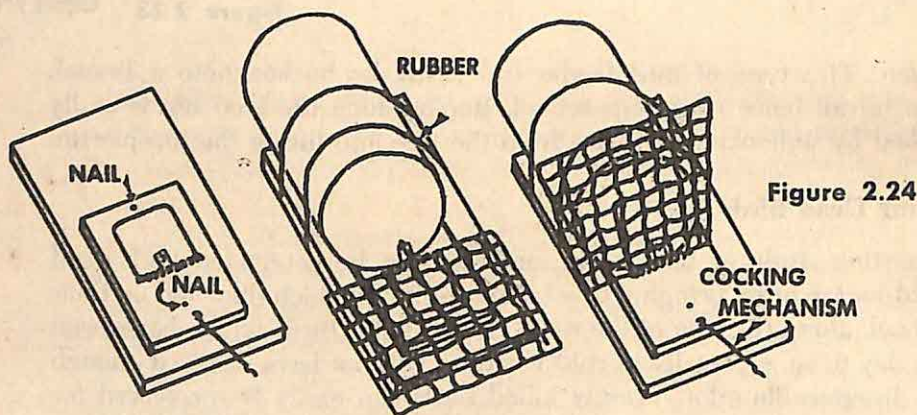


Figure 2.24

Discussion: You now have a trap that will catch small live mammals such as field mice, house mice, and others in the manner illustrated in Figure 2.24(c). Setting the trap is easy: place a dab of peanut butter on the bait tray and set the mechanism as illustrated in Figure 2.24(b). Place some cotton or dried grass inside the trap (can) to keep the small mammals from suffering due to a possible drop in temperature.

To catch field mice, set the trap in the grass of an open field where you have discovered mice runways. Field mice can also be found near rock piles, under old rotted logs, and under boards. Place the trap in the vicinity of such places. Check the traps daily without fail. Remember animals need food and water to survive. After capturing a small mammal, release it into a cage which you have prepared for it. Wear gloves when handling these wild animals. They may snap at you.

2. Studying Animal Tracks (Activity 4-6)

Materials: Dry plaster of paris, tin can, water, and several one-inch wide strips of cardboard of varying lengths.

Procedure: Locate some animal tracks in firm mud, frozen ground, or frozen snow. Clear out any debris that you may find in the track, such as bits of leaves or twigs, and sprinkle talcum powder in the track, blowing out the excess to give the imprint a smooth surface. Place a cardboard strip around the track to form a reservoir for the liquid plaster of paris. Mix the plaster of paris with water in a tin can until it is of a milk-like consistency. Mix only what can be used at that time. Pour the plaster of paris into the cardboard reservoir and let it dry. After the plaster becomes firm, lift it from over the animal track.

Discussion: You will have a cast of the animal track, showing the detail of the toes and claws. If you desire to make a mold of the track, press the cast into a layer of modeling clay. Much can be learned about the activities of the local wildlife of the area by studying animal tracks without actually seeing the animal itself.

3. Collecting Skulls (Activity 4-6)

The key to the classification and identification of many animals is the skull. The formation of the bones and type of teeth found in a skull provide positive identifying characteristics of animals, especially mammals. Mammal skulls can be found in wooded areas and under rocks and old logs where they crawled to die. The carcasses of animals who fell victim to predators, starvation or the bitter cold of winter can be found in open fields where they fell. Many of the skulls will be stripped of flesh and bleached by the sun. Others may still have some flesh remaining. If you are not squeamish, they can be carried home in a plastic bag and placed in a meal worm cage. Within a few days the meal worms will have eaten them clean for you.

From the skull collection one can study the various types of animal teeth. After investigating the incisor teeth of mice, rats, squirrels, woodchucks, muskrats, and beavers, you will quickly realize why they are all classified as rodents. Teeth are also a clue to the food habits of mammals. Compare the teeth of the flesh eating dog or cat with the grass eating horse or cow. Much can be learned about how animal teeth grow. Compare the rooted, sharp teeth of a dog with the flat, non-rooted, continuously growing teeth of the rabbit or muskrat. Much can be learned about the benefit that these animals give or harm they do to man from studying the relationship of teeth and food habits of animals.

4. Collecting Dead Mammals (Activity 4-6)

Mammals which have been struck down by automobiles but are still intact make readily available study skins. Surprise your students some day by asking them to bring to school any dead animals they find along the road if the animals have not been dead for more than a day or two and their internal organs are not exposed. These dead animals can be put into a shoe box and brought to school. Freshly killed mammals can easily be preserved for long periods of time if injected with a 10 per cent formalin solution using a 25 cc

hypodermic syringe. Insert a number 20 needle into several different places in the body cavity, neck, head, legs, and feet and inject the formalin solution. Hospitals, clinics, and veterinary hospitals that use penicillin usually dispose of the syringe after one use. These institutions are usually quite willing to let you have them for your classroom projects. A study of the feet, claws, teeth, fur, and tails of these animals could be made and the animal discarded within a few days by the person who brought it to school.

5. Collecting Animal Scats (Activity 4-6)

Animals tracks are sure signs that animals are or were present. Tracks can be used to identify animals and as a clue to their activities. Animals leave other evidence of their past presence too in the form of *scats* or droppings. Even the least experienced *scatologist* can identify the droppings of a rabbit or dog. Many hunters are skilled scatologists and use the evidence they find to identify animals and determine how recently the animal was in the area. Scatology, however, can do more than identify animals. Scats can be used to make qualitative studies of the feeding habits of many mammals. The diet of the red fox has often been thought to be birds, especially chickens. However, a study of their scats will prove that the greater part of their diet consists of mice, rabbits, and fruits. The evidence is exhibited in the pieces of undigested bones, fur, and fruit pits found in the scats. If you know the skulls and teeth of mammals, you can easily identify many of the mammals which have been eaten. Owl pellets leave behind the evidence of the diets of these birds. Pellets cannot really be classified as *scats* or droppings since the owl regurgitates these pellets. Nevertheless, they contain bones, fur, and the undigestible hard parts of insects. Your knowledge of skulls and teeth will thus come in handy once again in identifying these remains.

III



The Atom and Atomic Energy

The children of today are living in the atomic age and should be given the opportunity at an early age to become familiar with the atom and the secrets it holds in store for them in the future.

The following teacher demonstrations and student activities have been proven successful—for the author—in teaching the basic structure of the atom and the concepts of atomic energy.

It is suggested that study of the atom, as outlined in this chapter, be reserved for elementary children in the fifth and sixth grades.

A. THE STRUCTURE OF THE ATOM

1. The Size of the Atom (Demonstration 4-6)

Materials: Marbles, b-b's (buckshot pellets), a foot ruler, a straight pin, and some table salt.

Procedure: One of the first concepts which should be established when introducing the study of the atom is the concept of the size of the atom. Ask the children to estimate how many marbles will fit within the boundaries of one inch on a ruler. Have them actually place the marbles along one inch on their foot ruler. Hold up a b-b (buckshot pellet) and ask them to estimate how many b-b's will fit within the boundaries of the same inch if they were placed side by side. Next ask your students to estimate how many grains of salt will fit within the boundaries of one inch on their ruler. Have them actually place as many grains of salt as they can on an inch line, using a magnifying glass to aid them.

Discussion: Your students will discover that about two average size marbles will fit within the boundaries of the inch on their ruler. They will also dis-

cover that about ten b-b's will fit within the boundaries of the same inch. When they begin working with grains of salt, they will have difficulty manipulating them into place because of their size. Some one of the students usually comes up with a short cut to estimating the number of grains, such as placing enough grains side by side to equal one-fourth inch and then multiplying this number by 4. The average number of grains will be about 40 grains to the inch. If they use a magnifying glass, the children will also discover that salt grains are tiny cubes. Next ask the children to estimate how small they think the grains of salt would have to be to fit 250,000,000 (write this figure out so they can see it) grains within the boundaries of one inch. After the children have made some wild guesses (and some will be wild) ask them, "Do you think you would see one of these tiny grains of salt with just your eye? with a magnifying glass? with a microscope?" Many will agree that you will not be able to see them with your unaided eye or with a magnifying glass. Many will think that you probably will be able to see them with a microscope. Do not try to convince them otherwise at this time. Next tell them that there are tiny particles known to man small enough to fit 250,000,000 of them end to end within the boundaries of an inch. They are called *atoms*. To be even more convincing, hold up a straight pin and point to the head. Ask the students in the back of the room if they can see it. Some will not be able to see it unless it reflects the light in the room. Tell them what you have in your hand and have one of the students sitting close by verify it for you. Next tell them that 30,000,000 to 50,000,000 (write these figures out) atoms will fit on the head of the pin, which the students in the back of the room can barely see if they can see it at all.

The concept of the actual size of the atom is difficult to get across to the children. The best you can do is to try to impress them as much as possible by drawing comparisons with things they can see.

2. Introducing the Parts of the Simplest Atom: Hydrogen (Demonstration 4-7)

Materials: Flannel board, white construction paper, glue or rubber cement (not paste), strips of flannel.

Procedure: Draw and cut out two of each of the cartoons illustrated in Figure 3.1 and back them with strips of flannel so that they can be used with a flannel board. Letter and cut out the following words on white construction paper, using a felt pen, rubber stamp letters, or a stencil: *Peter*, *Proton*, *Ethel*, *Electron*, *Dud*, *Neutron*, *Nucleus*, *Space*, and *Center*. Glue a strip of flannel to the back of each word so that they can be used with a flannel board. The size of the lettering depends upon the distance from which they will be viewed.

Discussion: You now have the necessary equipment to make a flannel board presentation in cartoon form of the structure of the hydrogen atom. The following paragraphs provide a suggested sample presentation.

First, introduce the main parts of the hydrogen atom: the *center*, *space*, and *electron*. "The largest part of any atom is the space between the center and the electrons."

Next, substitute the word *nucleus* for *center* explaining that nucleus means center. Introduce Peter Proton as the part which makes up the center of the simplest atom, called *hydrogen*. Because we have one *Peter Proton* we must have one *Ethel Electron*. The three parts of the simplest atom are *Peter Proton* in the nucleus, space, and *Ethel Electron*. The next demonstration will explain their relationship in more detail.

3. Forces Which Hold the Atom Together (Demonstration 4-6)

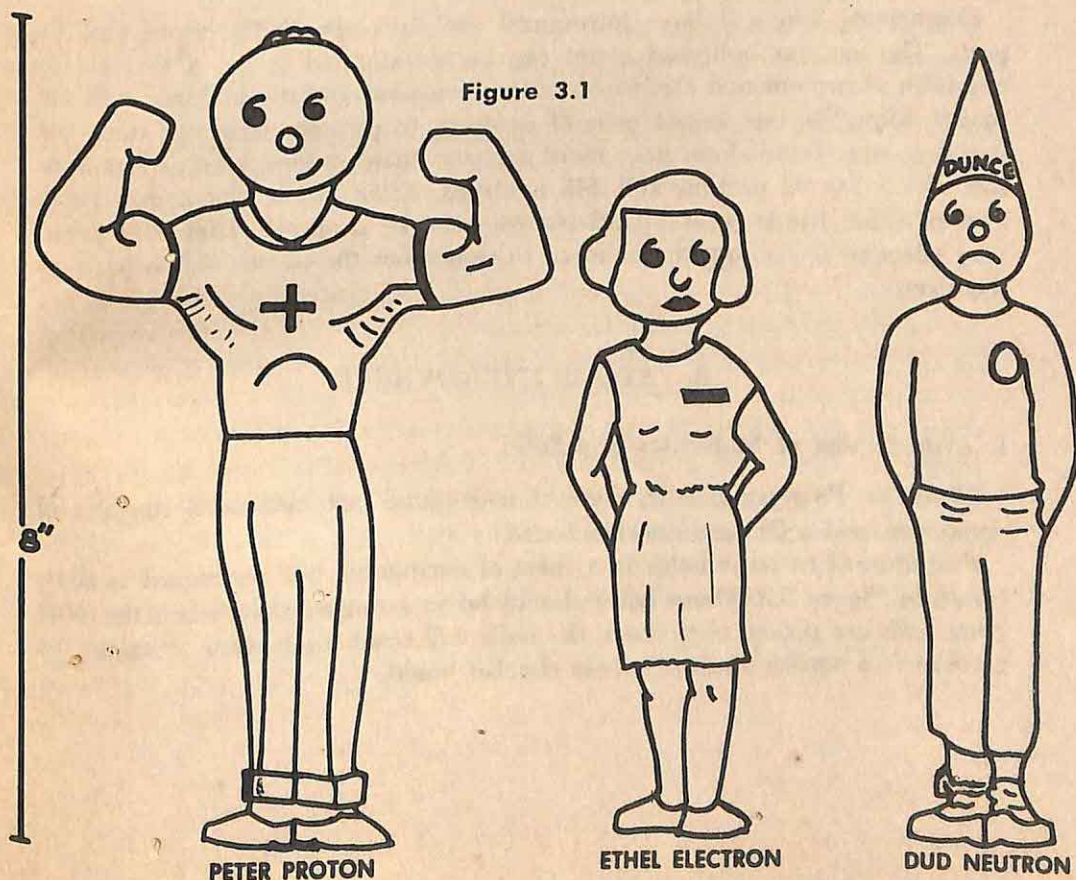
Materials: Ball, string, and tape.

Procedure: Attach a three-foot length of string to a tennis ball or rubber ball. Hold the end of the string in one hand and whirl the ball around in a circle over your head.

Discussion: The ball represents the single electron in the hydrogen atom, whirling around the nucleus, your hand. The string represents the attractive force created by the opposite charges of the negative electron and the positive proton.

In your description refer back to the cartoon figures on your flannel board and point out the *plus (+)* sign (indicating a positive electrical charge) on *Peter Proton's* shirt and the *minus (-)* sign (indicating a negative electrical charge) on *Ethel Electron's* blouse. Opposite charges attract like opposite poles of a magnet attract. (Demonstrate opposite poles of a magnet attracting.)

Present the children with this problem. If opposite charges attract, then why isn't *Ethel Electron* moving toward *Peter Proton*? Whirl the ball over your



head once again for the children to see how *Ethel Electron* whirls around *Peter Proton* but is not attracted to him. The answer will become obvious: the speed at which the electron is traveling prevents *Ethel Electron* and *Peter Proton* from getting together. We have two equal forces working in opposite directions—the outward force of the whirling body and the attractive force between the two bodies. This keeps the electron in orbit around the nucleus of the atom.

4. Introducing the Parts of the Next Simplest Atom: Helium (Demonstration 4-6)

Materials: Flannel board and flannel-backed cartoons as illustrated in Figure 3.1.

Procedure: In introducing the next simplest atom, *helium*, refer back to the flannel board with the parts of the simplest atom, hydrogen as explained in demonstration 3 above. Ask the children this question, "How many *Peter Protons* do you think the next simplest atom has?" Refer to the one to one ratio of electrons and protons in the hydrogen atom. "If this atom has two *Peter Protons*, how many *Ethel Electrons* do you think it will have?" The answer, undoubtedly, will be two protons and two electrons in the *helium* atom. The *helium* atom has another part in the nucleus, too, called neutrons. Introduce *Dud Neutron* to the flannel board next to the two *Peter Protons*. "How many *Dud Neutrons* do you think we should have?" The answer will probably be two, and it will be correct. You might explain that *Dud Neutron* gets his name from the fact that he has no charge. The "0" on his shirt indicates no charge.

Discussion: You will have introduced the structure of the atom and its parts. The more complicated atoms can be investigated to see if the one to one ratio of protons and electrons remains constant, and the children will see that it does. The one to one ratio of neutrons to protons, however, does not stay the same. Some atoms have more neutrons than protons, such as Uranium 238 which has 92 protons and 146 neutrons. After awhile the names *Peter Proton*, *Ethel Electron*, and *Dud Neutron* can be dropped. They will prove very effective in helping the children to remember the names of the parts of the atom.

B. ATOMS EVERYWHERE

1. Arrangement of Molecules in a Solid

Materials: Ping pong balls, sheet of corrugated box cardboard, marbles of equal size, and a Chinese checker board.

Procedure: Cut some holes in a sheet of corrugated box cardboard as illustrated in Figure 3.2. These holes should be so arranged that, when the ping pong balls are placed over them, the balls will touch each other. Arrange the marbles in a square on the Chinese checker board.

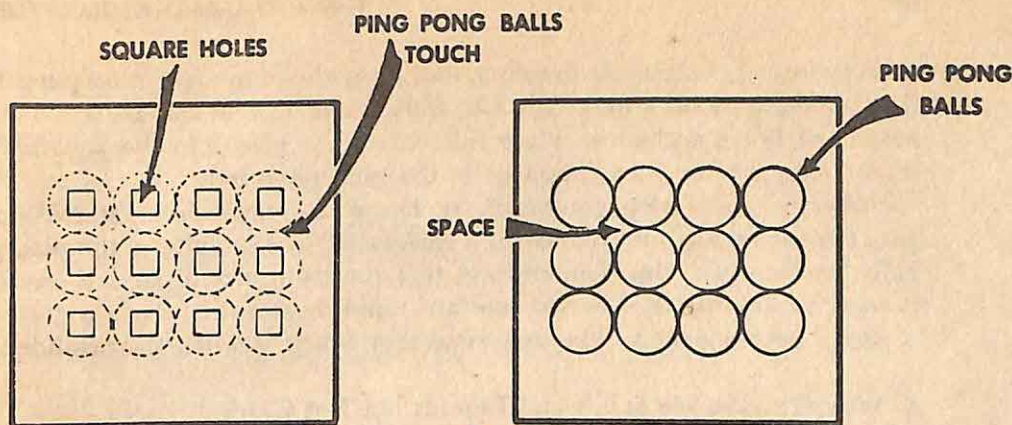


Figure 3.2

Discussion: The ping pong balls will represent *molecules*, which are atoms that are bound together, as they might be arranged in a solid. The molecules touch each other and *usually* form a geometric pattern. There is some space between the molecules, more in some solids than in others. The roundness of the ping pong balls will illustrate why there is space as shown in Figure 3.2. The marbles set in the holes on the Chinese checker board will illustrate the same principle. Use large marbles so they will touch each other.

2. Arrangement of Molecules in a Liquid (Demonstration 4-6)

Materials: Ping pong balls, wide-mouth gallon or mustard jar, quart jar, and marbles of equal size.

Procedure: Fill the wide-mouth gallon jar half full with ping pong balls. Fill the quart jar half full with marbles. Observe the arrangement of the ping pong balls and the marbles in the two jars. Compare this with the arrangement of the ping pong balls in Figure 3.2 and the marbles on your Chinese checker board. Screw the lids on both jars and tilt the jars so that the ping pong balls and marbles begin to move. Pour the ping pong balls into another container. What happens?

Discussion: The ping pong balls and marbles represent the molecules of a liquid. Their arrangement is random but they are touching each other. There is less space between the random arrangement of the balls and marbles in the jars than there is between the geometrically arranged balls in Figure 3.2 and the marbles on the Chinese checker board. The molecules can slide between each other to fill up most of the space in this random arrangement. In contrast to the rigid bonds between the molecules of a solid, the molecules of a liquid are not rigidly arranged, which allows them to roll over each other. The ping pong balls and marbles rolled over each other when the jar was tilted back and forth. They were able to be poured into another container.

3. Arrangement of Molecules in a Gas (Demonstration 4-6)

Materials: Wide-mouth gallon mayonnaise or mustard jar, ping pong balls, and a tank type vacuum cleaner.

Procedure: Fill the wide-mouth gallon jar with six to eight ping pong balls. Reverse the hose on a tank type vacuum cleaner so that the air is blown out instead of being sucked in. Place the end of the hose into the jar and blow the air into the jar. What happens to the ping pong balls?

Discussion: The ping pong balls represent the molecules that make up a gas. The forced air from the vacuum cleaner vigorously agitates the ping pong balls (molecules). This demonstrates that the molecules of air are constantly in motion. Because they are in constant rapid motion, they have a great deal of space between them. The only time they touch is when they collide.

4. Why We Can See Solids and Liquids but Not Gases

Materials: Table salt and a black sheet of construction paper 18 inches square.

Procedure: Pour some table salt in a small pile on a black sheet of construction paper. Ask the children if they can see the pile of salt from where they are seated. Take a *pinch* of salt between your fingers and drop one grain of salt in each corner of the black construction paper. Ask the children if they can see these grains of salt from where they are seated.

Discussion: The pile of salt represents many molecules. The molecules can be seen in the form of a solid or liquid when they are close together as they are in the pile. The molecules cannot be seen when they are spread out like those in a gas, as represented by the grain of salt in each corner of the paper.

C. ATOMIC ENERGY

1. Looking for an Active Substance to Produce Atomic Energy (Demonstration 4-6)

Materials: Geiger counter, clock with a radium painted dial that glows in the dark, pieces of iron, lead and aluminum.

Procedure: Energize your Geiger counter and probe the various materials listed above, listening for the clicking of the Geiger counter. Bring the probe next to the radium dial of the clock or wrist watch. What happens?

Discussion: A Geiger counter is a sensitive electronic device which can detect the presence of radioactive material by producing an indication on a dial or in an audio presentation. The audio presentation is a clicking noise which becomes louder and more rapid as the probe gets closer to the source of radioactive material. In this demonstration we are primarily interested in the audio presentation. As the probe is brought near the iron, lead, and aluminum, there is no increase in the number of clicks heard per unit of time. As the probe is brought near the radium dial on the clock, the number of clicks increases considerably until it becomes a loud "static" noise. This static noise is produced by the energy radiated by the splitting atoms of radium. The radium paint on the dial is a very unstable mineral, and the atoms split spontaneously and at random.

Your next question will probably be "Where do I get a Geiger counter?" Find out who is the civil defense chairman in your locality. Geiger counters are part of his equipment. He may even be able to recommend a qualified operator to help you. Another source is the Naval Reserve and Army Reserve training centers. Your own high school science department may have one too. Your local fire department or police department may have one on hand to aid in civil defense.

2. Demonstrating a Chain Reaction with Dominoes (Demonstration 4-6)

Materials: Set of dominoes.

Procedure: Set each domino on its end in a straight line about one inch apart with their flat sides facing each other. Push the first domino over onto the second domino. What happens?

Discussion: A *chain reaction* is the result. All the dominoes fall over one after the other. Atoms are split in chain reactions too. What starts a chain reaction? A chain reaction is started by a shooting "Dud Neutron." Scientists first split an atom by firing a neutron "bullet" which struck the nucleus of the atom, breaking its neutrons and protons apart. As the nucleus broke apart, it gave off large quantities of heat energy. As the neutrons split from the atom, they were like bullets which struck other nuclei and split them too. These atoms in turn released more energy and more neutrons, which split more atoms. The reaction continues at an unbelievable speed, creating great quantities of heat energy. The chief fuel is the mineral uranium, which is a very unstable substance, and chain reactions occur rapidly.

3. Demonstrating a Chain Reaction by Using Matches (Demonstration 4-6)

Materials: Box of wooden matches and modeling clay.

Procedure: Break off the match heads, leaving about three-fourths of an inch of the match stick attached. Use a soda bottle to roll out some modeling clay to a thickness of one-half inch. The size of the slab of clay depends on how large a demonstration you desire. Arrange the match heads in a pattern in the clay slab by forcing the broken end of the match into the clay so that the match head is in a vertical position. Be sure that the match heads are touching or almost touching. Strike a match and ignite one of the match heads stuck in the clay nearest you. What happens?

Discussion: A chain reaction occurs with each match head igniting the one next to it. As each additional match head ignites, the flame grows bigger, creating more and more heat. As a chain reaction continues in an atomic reactor, the heat energy becomes greater and greater too.

4. Demonstrating a Chain Reaction With Ping Pong Balls and Mouse Traps (Demonstration 4-6)

Materials: Large packing box, sheet of transparent plastic tape, 25 mouse traps, and 27 ping pong balls.

Procedure: Obtain a large packing box from a local appliance store and

cut off the flaps from the open end. (Note: TV packing boxes work very well.) Set the box on its side on a desk with the open end facing the children in the classroom. Cut a hole 3 inches square in the center of the top of the box. Set the tripping mechanism on 25 mouse traps and arrange them on the floor of the box as illustrated in Figure 3.3(a). Be very careful as you arrange the set traps, one false move and your work will go for naught. After the traps are arranged, carefully place a ping pong ball on each trap, as illustrated in Figure 3.3(b), and tape the sheet of clear plastic over the open end of the box.

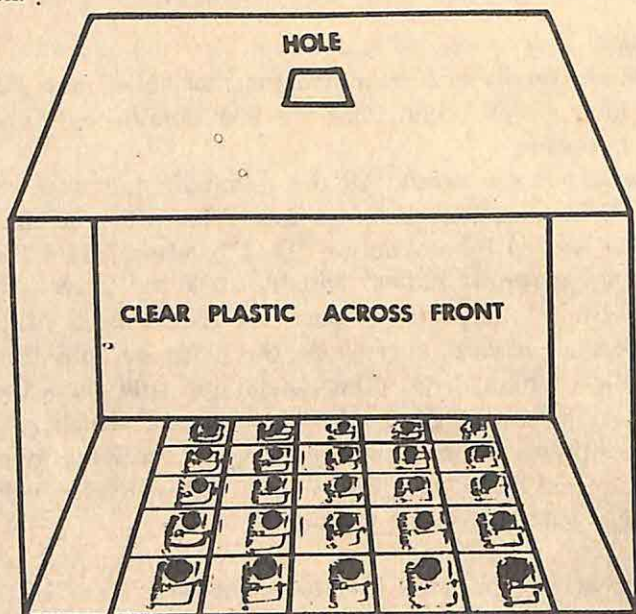
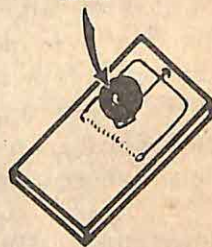


Figure 3.3

PING PONG BALL



Discussion: You are now ready to set off a chain reaction. Hold two ping pong balls in your hand with one of them over the small hole in the top of the box. Use some showmanship to build up the anticipation of the children; then drop one through the hole to begin the chain reaction of snapping mouse traps and flying ping pong balls. If the first ping pong ball does not trigger the chain reaction, drop in the one you have waiting in reserve. For the best results with this exciting demonstration, have it all set up before the children arrive and cover it with a sheet or other covering so that it is not given away.

5. Making a Model Atomic Reactor (Activity 4-6)

Materials: Three cardboard boxes of similar proportion but of different sizes, sheet of cardboard, and two cardboard cylinders made from paper towel rolls.

Procedure: Nest the three boxes as illustrated in Figure 3.4(a). The frames attached to boxes 2 and 3 are designed to center the boxes in one another as they are nested. Figure 3.4(b) shows the arrangement of the cardboard cylinders which pass through all three boxes. Cut two strips of cardboard to fit in each of the cardboard cylinders to a length as shown in Figure 3.4(b).

These will be the control rods which slide in and out of the *core* of the reactor.

Discussion: You have a cutaway model of an atomic reactor. The *core* of the reactor is in the center, just as the core of an apple is in the center. This is the compartment where the uranium fuel is producing energy from a chain reaction. Surrounding the *core* are *graphite* blocks. The graphite blocks help to control the chain reaction by absorbing some of the neutrons which might otherwise split other atoms, producing a greater amount of energy than desired. The control rods provide a finer control of the chain reaction. Some are made of graphite and will absorb neutrons too as they are drawn into the core. The more control rod surface exposed to the fuel, the more neutrons will be absorbed, thus slowing down the reaction. As the control rods are withdrawn, fewer atom splitting neutrons are absorbed, and the chain reaction is speeded up. Shielding from the radiation is

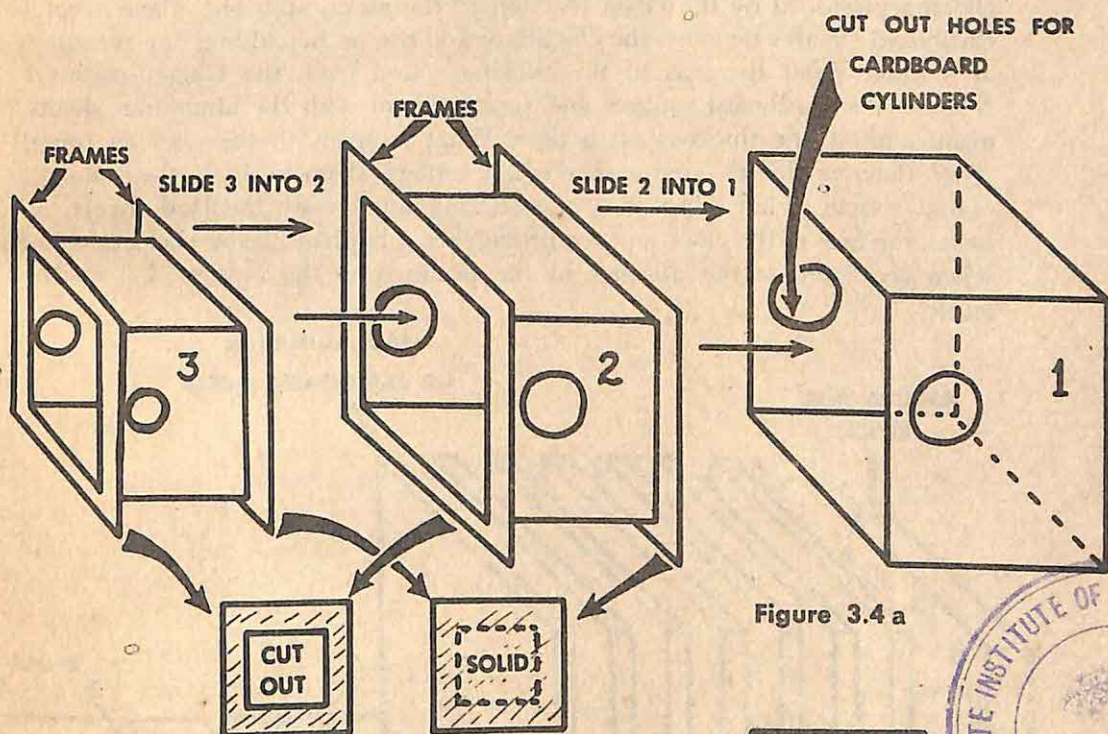


Figure 3.4 a

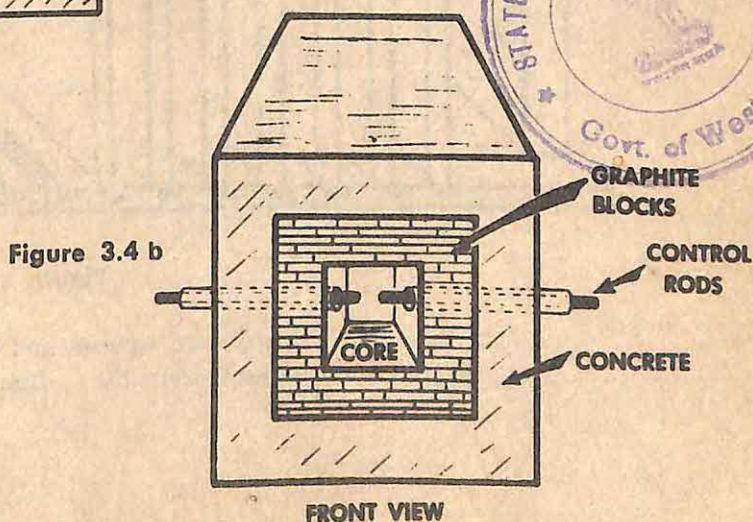
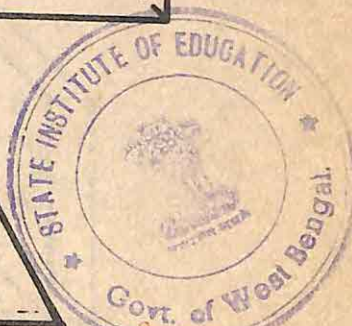


Figure 3.4 b



provided by a thick wall of concrete. The "concrete" shielding of your model reactor is the space between box No. 1 and box No. 2. One thing to be sure to tell your students is that the model reactor which they have made is one that has been cut in half so that they can see what is inside. In essence, it is a cross-section of a reactor. The use of reactors to produce heat for generating electricity and for running ships would make very interesting research for some of your students.

6. Shielding Against Radiation (Demonstration 4-6)

Materials: Geiger counter, some aluminum sheets, cardboard squares, lead sheets, and a radium dial clock or watch.

Procedure: Set up your equipment as shown in Figure 3.5. Place the Geiger counter probe about one foot from the radium dial clock and listen to the clicking produced by the chain reaction of the atoms splitting. Place several cardboard squares between the clock face and the probe, adding one thickness at a time. What happens to the clicking sound from the Geiger counter? Remove the cardboard squares and replace them with the aluminum sheets, again adding one thickness at a time. What happens to the clicking sound now? Remove the aluminum sheets and replace them with the lead sheets, one at a time. What happens to the clicking sound with the lead sheets between the face of the clock and the probe? What happens to the clicking sound when you increase the distance of the probe from the radium dial on the clock?

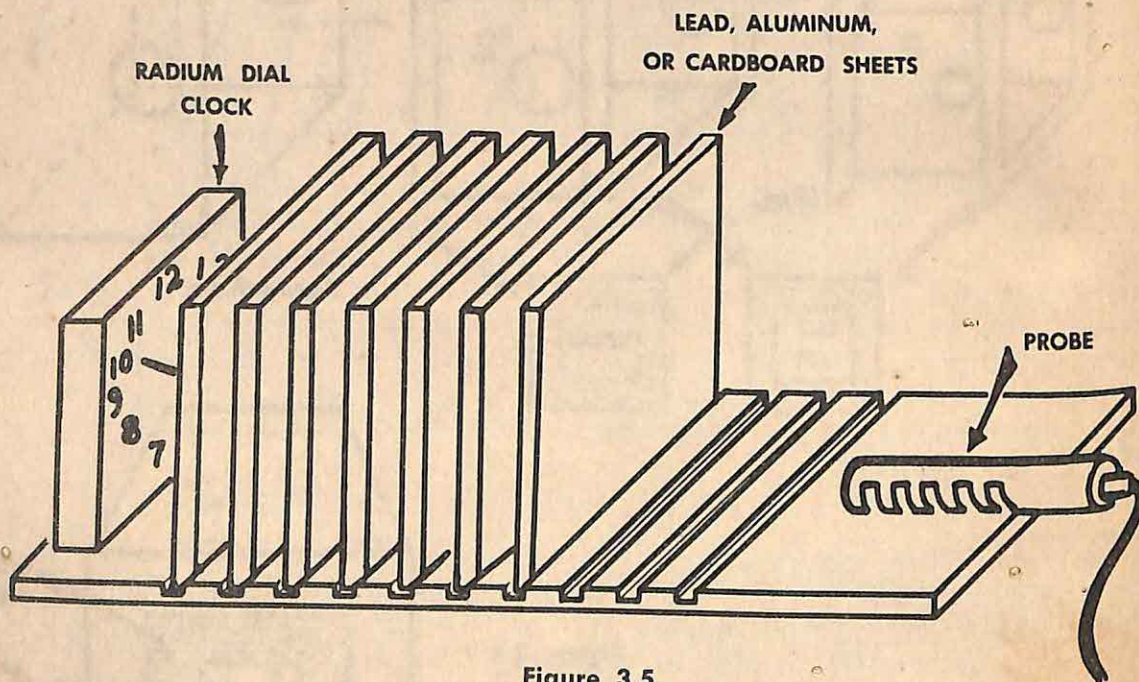


Figure 3.5

Discussion: The cardboard squares and the aluminum will have little effect on the radiation emitted from the radium dial, as will be indicated by the

Geiger counter. The lead sheets, however, will shield the probe from almost all the radiation, which becomes quite evident when listening to the ever decreasing number of clicks heard from the Geiger counter's audio system. Air can be a shield too. The greater the distance between the probe and the radium dial, the less intense become the radiation indications from the Geiger counter. Lead is an excellent material for shielding against radiation. An interesting sidelight activity would be to have the radiologist from the nearest hospital visit your classroom to discuss shielding from his X-ray machine. Ask him to bring his lead-lined gloves and apron with him. Maybe your class could visit him at the hospital.

IV



The Air Around Us

The study of *The Air Around Us* in the elementary school science program provides many exciting demonstrations and stimulating activities for the children at all levels in the elementary school.

The topics covered in this chapter emphasize the characteristics of air and related subjects, such as the earth's atmospheric pressure, the wind and the weather, clouds and the weather, weather instruments, and air and the airplane.

A. EXPERIMENTING WITH AIR

1. Air Is Something: It Takes Up Space (Demonstration K-6)

Materials: Four plastic bags, sand, stones, and water.

Procedure: Exhibit three plastic bags: one filled with sand, one with stones, and one with water. Exhibit a plastic bag which has been blown up with air and the end sealed. Compare the four bags.

Discussion: The sand, stones, and water fill the plastic bags and cause them to bulge because they are taking up space in the bags. The air in the bag makes the bag bulge too. Air is something—just as sand, stones and water are something. If your students in fourth, fifth, or sixth grade have studied atoms and molecules (as outlined in Chapter III), this demonstration can be used to show that molecules of air (gases) are taking up space in the plastic bag just as are the molecules which make up the molecules of sand, stones, and water.

2. Air Is Something Because We Can Feel It (Demonstration K-3)

Materials: Soda straw.

Procedure: Blow through a soda straw, directing the air against your hand. What do you feel?

Discussion: Although we cannot see the air we breathe, we can feel it. We can feel the force of the air as it is blown against our hand. We can see the effect of the force of the air when we direct the air through a straw at a sheet of paper or watch the wind out of doors make the trees bend.

3. Air Takes Space (Demonstration K-6)

Materials: Rubber balloon.

Procedure: Blow up the balloon and have the children observe what happens. What is causing the sides of the balloon to bulge?

Discussion: The balloon expands as air is forced into it. The more air that is forced in, the larger it becomes. For fourth, fifth, and sixth grade students that have studied atoms and molecules (as outlined in Chapter III), this demonstration can be used to show how the molecules of air cause the sides of the balloon to bulge as they are forced into the balloon.

4. Air Takes Up Space (Demonstration K-6)

Materials: Clear plastic tumbler, aquarium of water or gallon mayonnaise jar, paper towels, and tape.

Procedure: Tape a small piece of crumpled paper toweling to the inside bottom of a clear plastic tumbler. Have a student verify the fact that the towel is dry. Invert the tumbler and lower it vertically into the aquarium of water until it is completely submerged. Raise the tumbler out of the water and carefully remove the paper towel. Is it wet or dry? Why?

Discussion: The paper towel remains dry. The pressure of the air in the tumbler prevented the water from filling the entire space in the tumbler. The water, however, does rise a short distance in the tumbler, depending on how far the tumbler is submerged. Air must take up space.

5. Air Takes Up Space (Demonstration 4-6)

Materials: Clear plastic tumbler, aquarium filled with water, paper towels, and tape.

Procedure: Drill a small hole ($\frac{1}{8}$ inch in diameter) in the center of the bottom of the plastic tumbler. If a drill is not handy, heat a nail over a flame and melt a hole through the plastic tumbler. Tape a small piece of crumpled paper toweling to the inside bottom of the tumbler. Do not allow the tape to cover the hole. Invert the tumbler and lower it vertically into the aquarium of water, with your second finger covering the hole, until it is completely submerged. Raise the tumbler out of the water and carefully remove the towel. Have one of the children inspect the towel to see if it is wet or dry. Explain to the children that scientists always perform an experiment more than once to insure that their results are correct. Repeat the demonstration with one exception: slide your finger from over the hole; then lower the tumbler into the water as before. What happens to the paper towel this time?

Discussion: The paper towel will get wet as the air escapes through the hole and the water rises in the tumbler. The children will be slightly confused

and will accuse you of everything from trickery to witchcraft. Act puzzled and confused yourself; then ask them to try the same experiment at home that evening and report their findings to the class and you the next morning. Do not, of course, allow them to see the hole in the bottom of the tumbler. The problem that you want them to solve is why the paper towel got wet. If the air escaped, how did it escape? The next day repeat the demonstration, keeping your finger over the hole so that the paper remains dry. Try it again, allowing the air to escape; make sure you perform the demonstration in exactly the same manner as before. The paper towel could only get wet if the air were allowed to escape, and it did through the hole.

6. Air Takes Up Space (Demonstration K-6)

Materials: Aquarium filled with water, glass jar, and rubber hose.

Procedure: Submerge a glass jar in the aquarium and allow it to fill up with water. Place one end of the rubber hose in the jar so that it reaches the bottom, holding the other end out of the aquarium. Invert the jar with rubber hose so that it is mouth down in the aquarium. Blow through the other end of the hose. What happens to the water in the jar?

Discussion: The air pressure forces the water out through the mouth of the jar. The jar is now filled with air instead of water.

7. Air Takes Up Space (Demonstration 3-6)

Materials: Aquarium filled with water and two glass jars.

Procedure: Submerge one jar in the aquarium and allow it to fill with water. Invert this jar so that its mouth is resting on the bottom of the aquarium. Lower the second jar into the water mouth first so that the air pressure keeps the water out. With one hand lift the water-filled jar to a height which will allow the air-filled jar to pass under it. Tilt the *air-filled* jar so that the air bubbles rise and enter the *water-filled* jar. What happens?

Discussion: If performed carefully, the air in the *air-filled* jar will replace the water in the *water-filled* jar. The air in the original *air-filled* jar will be replaced by the water in the aquarium. Air takes up space.

8. Air Takes Up Space (Demonstration 3-6)

Materials: Aquarium filled with water, glass jar, and a piece of cork.

Procedure: Float a small cork on the surface of the water in the aquarium. Lower an air-filled jar *mouth first* over the cork and force it down into the water. What happens to the cork? What happens to the level of the water on which the cork is floating? Why?

Discussion: The air in the jar exerts a pressure on the water, preventing the water from entering the jar. As the jar is lowered into the water, the surface on which the cork is floating is forced down. Air takes up space and exerts a pressure.

9. Air Has Weight (Demonstration 4-6)

Materials: Yard stick, two balloons, foot ruler, desk, tape, and a balance scale.

Procedure: Tape a balloon to each end of a yardstick and balance the yardstick on the edge of a foot ruler which has been taped to the top of a small desk as illustrated in Figure 4.1(a) and (b). Mark the balance point on the yardstick. Remove one balloon and inflate it with air. Replace the blown up balloon to the end of the yardstick one again. What happens?

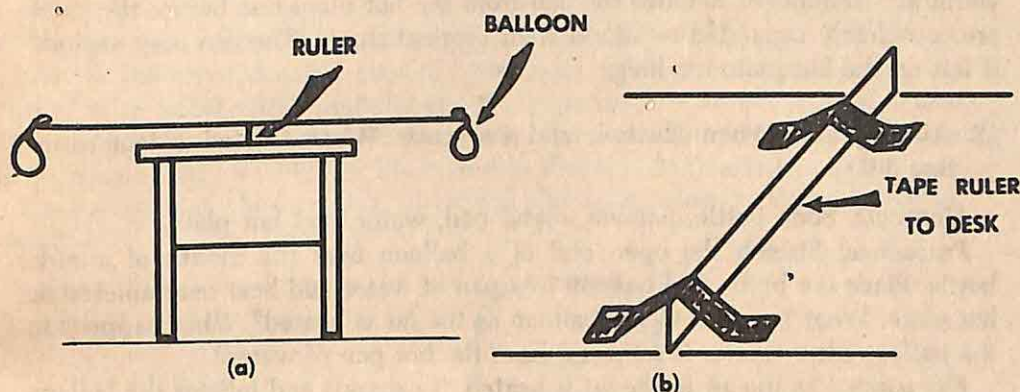


Figure 4.1

Discussion: The yardstick will no longer balance as before. It will tilt toward the inflated balloon, indicating that some weight has been added to that end. In fact, it has: the weight of the air in the balloon has been added.

Although this demonstration can be done with very simple equipment, it is difficult to set up. All windows and doors in the room should be shut and the movement of the children restricted to prevent air currents, which would upset the balance of the balloons attached to the yardstick.

An easier way to conduct this demonstration is with a laboratory balance scale. Balance the balloons on the platforms and then inflate one of them as before. The scale will indicate that the inflated balloon had more weight.

10. Air Expands When Heated (Demonstration K-6)

Materials: Soda bottle, cork, metal pan, water, and hot plate.

Procedure: Insert a cork or rubber stopper snugly in the opening of a soda bottle. Place the soda bottle in a pan of water and heat the water over an electric hot plate. What happens? Why?

Discussion: As the water is heated, the air inside the soda bottle is heated, too. It expands and forces the cork to fly off the opening of the bottle with a loud pop.

11. Air Will Expand When Heated (Demonstration K-6)

Materials: Gallon tin can with screw-on lid and hot plate.

Procedure: Obtain an empty gallon tin can and cave in its sides by stepping on it. A duplicating fluid can will work well but be sure to rinse the insides with soap and water before using because duplicating fluid is inflammable. Screw the lid on tightly and place the can on a hot plate to heat it. What happens to the can?

Discussion: The air inside the can is heated and begins to exert pressure on the crushed sides as it expands. The sides are pushed out by the expanding warm air. *Reminder:* Remove the can from the hot plate just before the sides are completely expanded to almost their original shape. The can may explode if left on the hot plate too long.

12. Air Expands When Heated, and Contracts When Cooled (Demonstration 3-6)

Materials: Soda bottle, balloon, metal pan, water, and hot plate.

Procedure: Stretch the open end of a balloon over the mouth of a soda bottle. Place the bottle and balloon in a pan of water and heat over an electric hot plate. What happens to the balloon as the jar is heated? What happens to the balloon after the jar is removed from the hot pan of water?

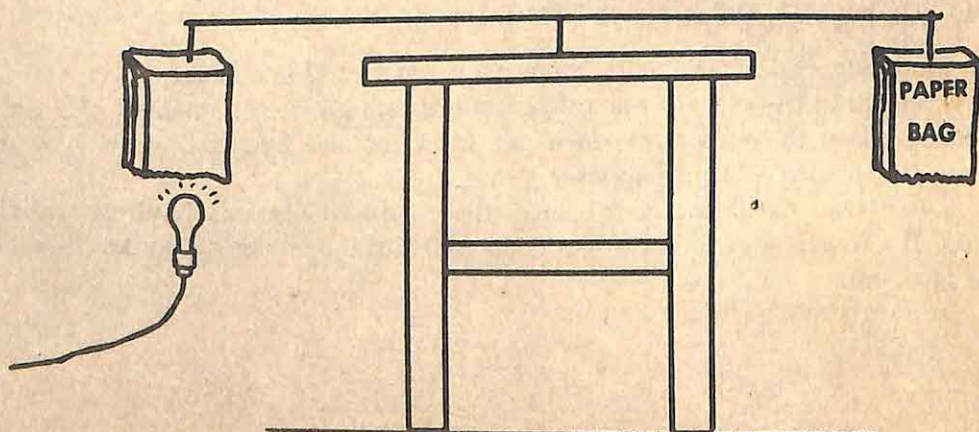
Discussion: As the air in the jar is heated, it expands and inflates the balloon with warm air. The air in the bottle and balloon cools and contracts after the bottle is removed from the hot water.

13. Warm Air Is Displaced by Cool Air and Made to Rise (Demonstration 4-6)

Materials: Yardstick, foot ruler, two paper bags, desk, tape, and electric light bulb.

Procedure: Fasten a bag open end down from each end of a yardstick as illustrated in Figure 4.2. The foot ruler will act as the fulcrum in the manner illustrated in Figure 4.1. Balance the yardstick with bags attached on the edge of the foot ruler. Place a lighted electric light bulb under the open end of one paper bag as illustrated in Figure 4.2. What happens? Why?

Figure 4.2



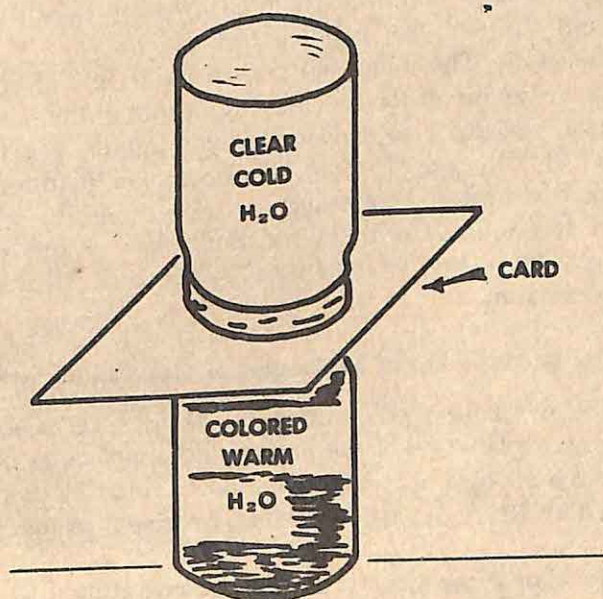
Discussion: The bag above the light bulb begins to rise. The air inside the bag is heated by the bulb. The air expands and some of it escapes, reducing the weight of the air inside the bag. The heavier cooler air surrounding the bag exerts a force on the lighter warm air; hence the bag moves up. There are fewer *molecules* of air in the bag since they were forced out when the air was heated. With fewer *molecules* of air in the bag it weighs less.

14. Cold Water Displaces Warm Water (Demonstration 4-6)

Materials: Two jars of identical shape and size, ink, water, and a 3 by 5 inch card.

Procedure: Fill two jars with water, one with warm water and the other with cold water. Pour a few drops of ink into the warm water to color it. Cover the mouth of the *cold* glass of water with a 3 by 5 inch card. Invert the *cold* glass of water over the *warm* glass of water, taking care to line up the lip of one jar with the other as illustrated in Figure 4.3. Carefully slip the card out from between the two jars, observing the water closely. What happens? Why?

Figure 4.3



Discussion: The clear cold water of the top jar will sink into the bottom jar of warm colored water, forcing the colored water up into the upper jar quickly. The displacement of warm water can be seen before diffusion is complete.

Warm and cold water react in much the same manner as warm and cold air and many times can be substituted—for demonstration purposes—for the invisible air.

15. Warm Water Will Be Found Above Cold Water (Demonstration 4-6)

Materials: Two jars of identical shape and size, ink, water, and a 3 by 5 inch card.

Procedure: Same as for demonstration 14 with the following exception: reverse the jars so that the warm colored water is on top and the clear cold water is on the bottom. Carefully slip out the 3 by 5 inch card and observe what happens.

Discussion: The warm colored water in the top jar does not displace the cold clear water in the bottom jar. Cold water, like cold air, is heavy and sinks. Warm water, like warm air, is found above cold water. This concept can be used later in the study of weather.

16. Cold Air Displaces Warm Air (Demonstration 4-6)

Materials: Hot plate, tin can, milkweed pod seeds or bits of cotton, and a puncture type can opener.

Procedure: Puncture several holes in the closed end and sides near the open end of a tin can and place the open end over the burner of a hot plate. Place some milkweed pod seeds or bits of cotton over the holes in the top of the can and observe what happens to them.

Discussion: The milkweed pod seeds or bits of cotton will appear to float up above the top of the tin can. The burner of the hot plate heats the air inside the can, causing it to expand, become lighter, and be forced up by the cold air which displaces it. Cool air also rushes in through the lower side holes where it is heated, continuing the process. As the warm air expands, it cools again and sinks. The milkweed pod seeds or bits of cotton will follow the path of the warm and cold air. Try the same demonstration using the classroom radiator.

17. Air Is Made Up of Molecules of Gas (Demonstration 4-6)

Refer to Chapter III, Section B, "Atoms Everywhere," demonstration 3 and 4, for an explanation of the nature of the molecules of the air.

Air is a mixture of gases composed of about 80% nitrogen, about 19% oxygen, and a 1% mixture of carbon dioxide, hydrogen, argon, helium, neon, and others.

18. Air Can Flow Like Water (Demonstration 4-6)

Materials: Two balloons, water, and a large jar.

Procedure: Fill one balloon with water and inflate a second balloon with air. Hold the neck of the water-filled balloon over the mouth of a large jar. Squeeze the balloon, releasing the neck so that the water falls into the jar. Now pinch the end of the inflated balloon with the thumb and forefinger of one hand and squeeze the balloon with the other hand. Release your finger grip slightly on the neck end of the balloon as you squeeze. Aim the neck of the balloon at the hand of one of your students. What does he feel?

Discussion: The water in the first balloon was released in a swift stream from the neck of the balloon when you squeezed it. The air in the inflated balloon was released in a swift stream of air in much the same manner as the water. Air can flow, too, like water. Again we use water to demonstrate the characteristics of air.

19. Air Is Found in Water (Demonstration K-6)

Materials: Glass jar and water.

Procedure: Fill a jar with cool water and allow it to stand for several hours. What do you observe on the walls of the glass on the inside?

Discussion: Tiny air bubbles begin to form on the inside walls of the glass. As the water conducts heat from the surrounding air, the dissolved air is driven out of the water and forms tiny air bubbles on the inside walls of the glass jar.

20. Air Is Found in Soil (Demonstration K-6)

Materials: Jar of sand, garden soil, and water.

Procedure: Pour some water into a jar of sand and observe the surface of the sand at the mouth of the jar. What do you observe? Pour some water into a jar of fluffy garden soil and observe the surface of the soil at the mouth of the jar.

Discussion: As the water is poured into the sand and garden soil, air bubbles appear at the surface. The air comes from the spaces between the particles of sand and soil as it is displaced by the water. Small holes can be observed at the surface of the sand after the water has filtered below the surface. These holes were formed by the escaping air from the soil.

21. Air in Plants (Demonstration 4-6)

Materials: Large jar of water, celery, and a pair of pliers.

Procedure: Submerge one end of a stalk of celery in the jar of water. Squeeze the end of the celery stalk with the pliers. What do you observe?

Discussion: Tiny bubbles will be observed rising in the water as the celery stalk is crushed by the pliers. The air is forced out from within and from around the plant cells of the celery stalk.

B. THE EARTH'S ATMOSPHERIC PRESSURE

1. The Envelope of Air that Surrounds the Earth

Materials: One foot diameter globe, a sheet of white cardboard 18 inches square, and a pencil compass.

Procedure: Find the center of the sheet of white cardboard and mark it. Using a pencil compass, draw a circle with a diameter of one foot. Draw another circle with a diameter of $13\frac{1}{2}$ inches using the same center. You will

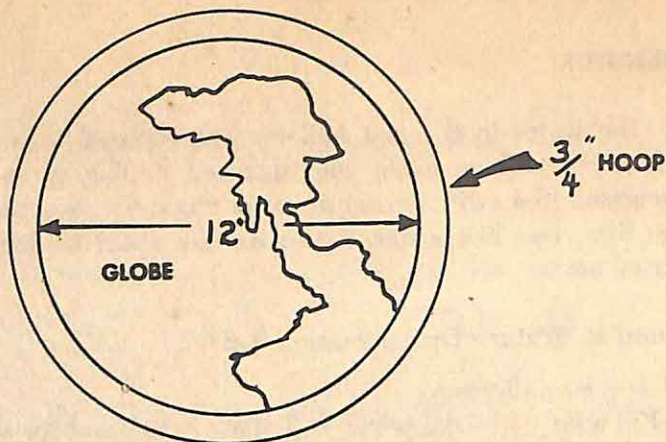


Figure 4.4

have drawn a hoop $\frac{3}{4}$ inches wide on your sheet of cardboard. Cut this hoop out of the sheet of cardboard, taking pains to insure that the edges are not ragged. Slip the hoop over the outside of a one foot diameter globe as illustrated in Figure 4.4.

Discussion: The white hoop represents the envelope of air around the earth at a true scale of one foot to each 8,000 miles. The diameter of the earth is about 8,000 miles. The earth's atmosphere extends to about 500 miles. Three-fourths of an inch represents 500 miles at this scale of one foot per 8,000 miles. The children will see a true scale picture of the earth's atmosphere in relation to the earth. If a 12 inch globe is not available, the scale proportion between the globe and the atmosphere is 16 (earth) to 1 (atmosphere). Thus a 9 inch globe would have an atmosphere of $\frac{9}{16}$ of an inch, an 18 inch globe would have a $1\frac{1}{8}$ inch atmosphere, and a 24 inch globe would have a $1\frac{1}{2}$ inch atmosphere.

2. The Atmosphere Exerts a Pressure on All Things on Earth in All Directions (Demonstration 4-6)

Materials: Glass jar, water, and a thin sheet of cardboard.

Procedure: Fill a jar with water and covers its mouth with a thin 3 by 5 inch sheet of cardboard. Hold the card with one hand and grasp the glass with the other hand. Invert the glass and let go of the card. What happens? Why?

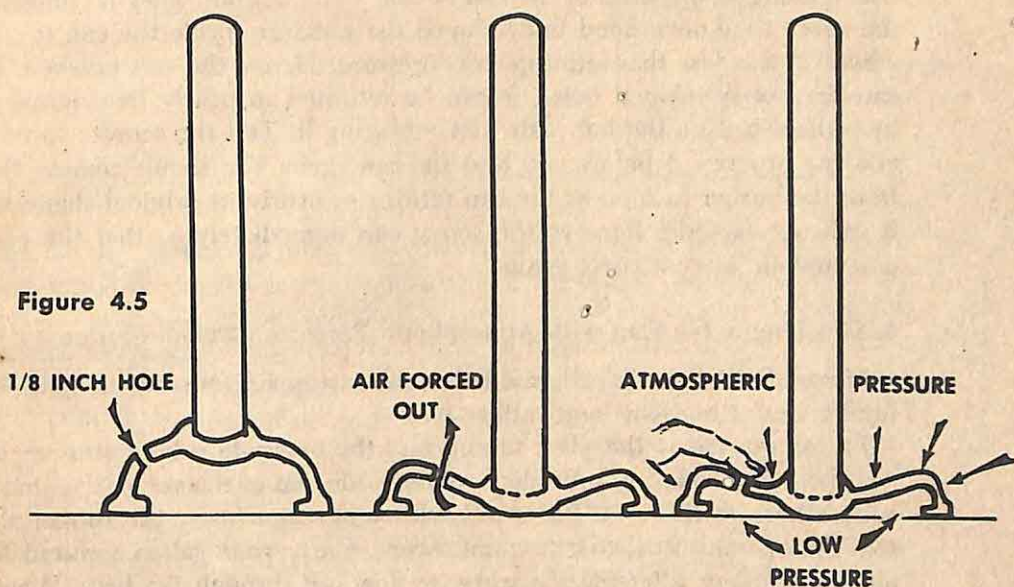
Discussion: The card remains in place, holding the water in the glass. The atmospheric pressure pushing up from under the card is greater than the force of the weight of the water pushing down on the same area of the card. The overall pressure on top of the card is less than that pushing up from under the card.

3. Atmospheric Pressure and the Plumber's Plunger

Materials: Plumber's plunger.

Procedure: Cut a small hole about an eighth inch in diameter in the top of a plumber's plunger as illustrated in Figure 4.5. Moisten the edges of the plunger with water before using. Have a small girl and a husky boy come to the front of the room to perform this demonstration. Have the husky boy push the plunger against the chalk board, collapsing the rubber plunger as

far as it will go. Have the small girl place her finger over the hole and ask the husky boy to pull the plunger from the board. He must, however, pull the plunger out at a 90° angle from the board and not tilt the handle up or down. Can he do it? If not, why not?



Discussion: As long as the girl keeps her finger over the hole in the plunger and does not allow the air to enter the plunger to equalize the pressure inside with atmospheric pressure outside, the husky boy will not be able to pull the plunger from the board. The 500 mile high atmosphere is pressing down on every square inch of the plunger with a weight of about 15 pounds. The plunger has roughly 28 square inches of area. This means there is approximately 420 pounds of pressure holding it to the chalk board. This is quite a bit more weight than the average man can lift. Just for fun have the small girl remove her finger from the hole and release the plunger from the board after the husky boy has tried in vain to pull it away.

4. Crushing a Tin Can with Atmospheric Pressure (Demonstration 4-6)

Materials: Gallon tin can with screw-on lid and hot plate.

Procedure: Pour an ounce or two of water in a gallon tin can and heat to a boil on a hot plate with the lid removed. Be sure to clean out the contents of the can with soap and water before using: the previous contents may have been an explosive fluid. After the water has boiled for a few minutes, remove the can from the hot plate and immediately screw the lid on tightly. Allow the can to cool. What happens to the can? Why?

Discussion: The can will begin to collapse from the force of the atmospheric pressure. As air in the can was heated, it expanded and most of the air molecules were forced out of the can through the opening. The molecules of water

vapor from the boiling water took up the space of the escaping air molecules and forced most of the air out of the can. When the lid was screwed on tightly and the can was allowed to cool, the can began to collapse. The molecules of water cooled, too; they condensed and formed droplets of water which clung to the sides of the can or fell to the bottom. They no longer filled the space they once filled but reduced the pressure inside the can to a point where it was less than atmospheric pressure. Hence the can crushed. If the can has not developed holes, it can be returned to nearly its original shape by replacing it on the hot plate and reheating it. Test the screw cap to see if you can unscrew it before you heat the can again. You should remove the can from the burner as soon as the can returns to nearly its original shape so that it will not explode. Remove the screw cap immediately so that the can will not implode after it cools again.

5. Crushing a Tin Can with Atmospheric Pressure (Demonstration 4-6)

Materials: Gallon tin can, one hole rubber stopper, four inch length of glass tubing, and a ten foot long rubber hose.

Procedure: Insert the glass tubing into the one hole rubber stopper, allowing about $2\frac{1}{2}$ inches to protude from the wide end of the stopper. Connect the rubber hose to this end. Fill a can with water and insert the rubber stopper into the opening so that it is quite secure. Carry your gallon can and hold it out the window, allowing the water to flow out through the hose. What happens to the can? Why?

Discussion: As the water flows out of the can through the hose, the can begins to collapse. The force of gravity causes the water to fall from the can through the hose. As the water falls from the second story, it picks up speed, and the partial vacuum it causes in the can is not great enough to hold it back. At the same time, atmospheric pressure is pushing on all sides of the can. As the pressure inside of the can becomes less than the atmospheric pressure outside, the can begins to collapse under the weight of the atmosphere. With the hose filled with falling water, air cannot make its way into the can to allow the pressure to equalize inside the can. If this demonstration does not work the first time, check your one hole rubber stopper to see if it is allowing air to leak into the can.

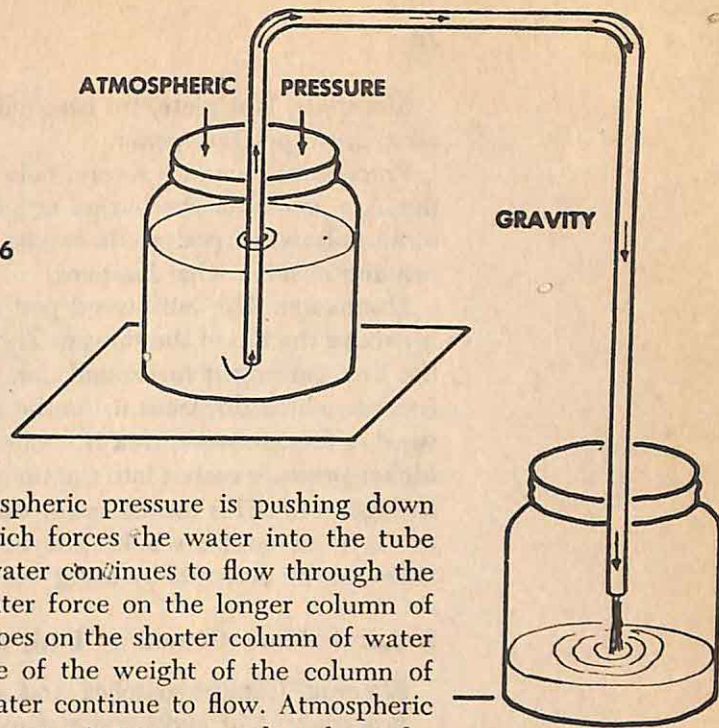
6. A Siphon Operates with Atmospheric Pressure

Materials: Two glass jars, clear plastic hose, vegetable coloring, and water.

Procedure: Fill one jar with water and add some vegetable coloring. Place the jar of water on a desk and an empty jar on the floor. Put one end of the clear plastic hose in the jar of water and put the other end to your lips. Suck on the tube as you would on a soda straw and observe the colored water as it is drawn into the tube. As it gets within a few inches of your lips, remove the tube from your lips and quickly place it in the empty jar. What happens? Why?

Discussion: As the air is drawn from the tube, the water is forced into the

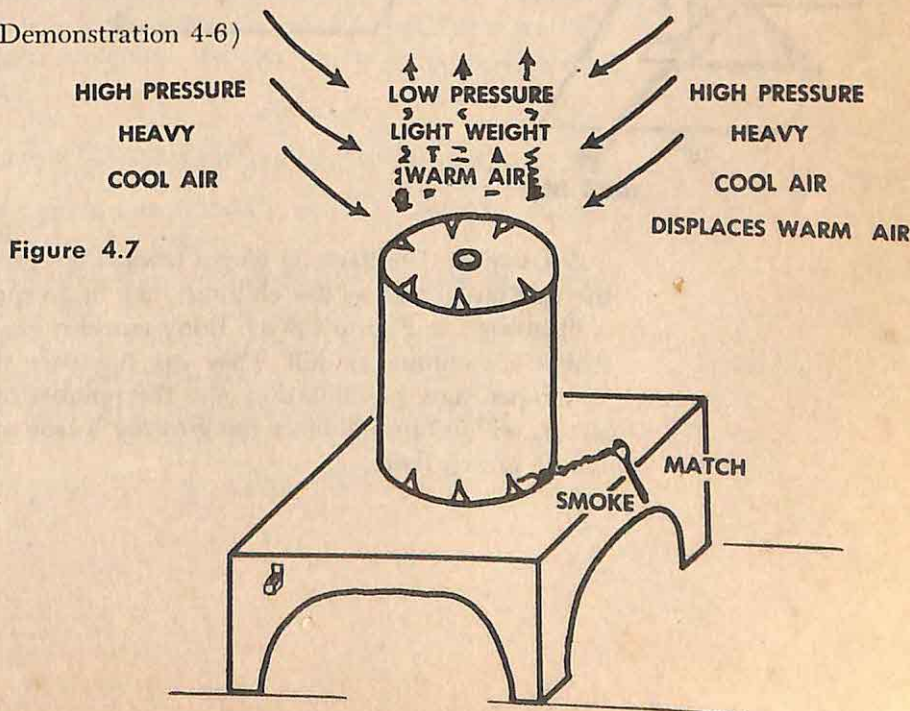
Figure 4.6



tube to fill the partial vacuum. The atmospheric pressure is pushing down on the surface of the water in the jar, which forces the water into the tube when the partial vacuum is created. The water continues to flow through the tube aided by gravity, which exerts a greater force on the longer column of water emptying into the lower jar than it does on the shorter column of water leading from the upper jar. It is the force of the weight of the column of water in the longer tube that makes the water continue to flow. Atmospheric pressure on the surface of the upper jar of water is great enough to keep the short tube full. Refer to Figure 4.6, which illustrates the operation of a siphon. What would happen to the flow of the water if the lower jar were raised above the upper jar before the latter were emptied? What would happen to the flow of water if the two jars were at the same level? Siphons make convenient devices for transferring liquids from one container to another if they are too heavy to pour by tipping. Siphons are also used to draw off liquids from containers without disturbing sediment, which might have accumulated at the bottom of the jar.

C. THE WIND AND OUR WEATHER

1. How Winds Are Caused (Demonstration 4-6)



Materials: Hot plate, tin can, milk weed pod seeds or bits of cotton, and a puncture type can opener.

Procedure: Puncture several holes in the top and sides of a tin can and place the open end over the burner of a hot plate as illustrated in Figure 4.7. Place some milk weed pod seeds or bits of cotton over the holes in the top of the can and observe what happens.

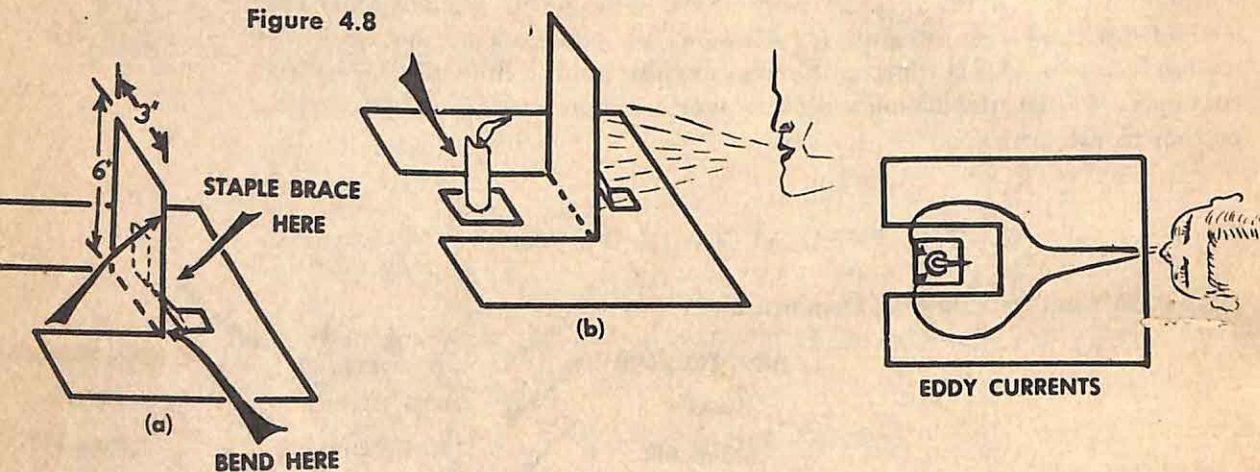
Discussion: The milk weed pod seeds or bits of cotton will appear to float up above the top of the tin can. The burner of the hot plate heats the air inside the can, causing it to expand, become lighter, and be forced upward by the cool air which displaces it. As the air inside the can is heated and forced upward, a *low pressure* area is created inside the can. The *heavier* cooler air of *higher pressure* rushes into the tin can through the low side holes as illustrated in Figure 4.7. This movement of *heavier, high pressure* air to *light weight, low pressure* air causes winds. The flow of the cooler air through the low side holes can be detected by using burning matches as illustrated in Figure 4.7.

2. Local Winds Caused by Eddy Currents (Demonstration 4-6)

Material: Candle, matches, and a sheet of cardboard.

Procedure: Cut and bend a sheet of cardboard in the manner illustrated in Figure 4.8(a). Place a lighted candle behind the cardboard flap as illustrated in Figure 4.8(b). Blow against the cardboard flap and observe the direction of the flame. In which direction is the flame blown? Why?

Figure 4.8



Discussion: The flame is blown toward the cardboard instead of away from the cardboard flap as the children may first expect. The direction of air flow is illustrated in Figure 4.8(c). Eddy currents are often caused when the wind strikes a mountain or hill. They can influence the local weather of an area, its temperature, precipitation, and the number of frost free days. All of these factors will in turn influence the growing season of an area and the crops which can be grown there.

3. Making a Transit (Activity 4-6)

Materials: Wooden board $\frac{1}{2}$ inch by 2 inches by 12 inches, modeling clay, thread, soda straw, tape, two small nails or brads, and a plastic protractor.

Procedure: Construct a transit as illustrated in Figure 4.9. Glue a plastic protractor to one side of the board so that the radius center of the protractor and the 90° mark line up with the top edge of the board but about $\frac{1}{16}$ inch below the top edge. The $\frac{1}{16}$ inch margin will provide enough room to allow a nail to be driven into the wood through the radius center of the protractor. It will not greatly affect the accuracy of the angle reading. Suspend a clay weight on a string from a nail which penetrates the radius center of the protractor. Fasten a soda straw to the board for sighting as illustrated in Figure 4.9.

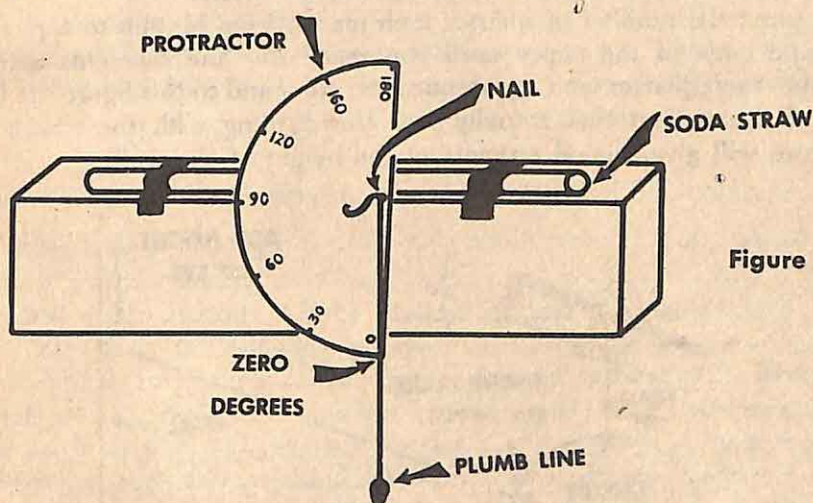


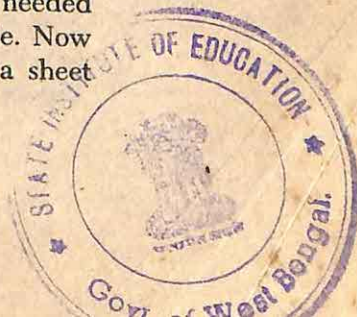
Figure 4.9

Discussion: You now have an instrument for measuring angles; it is called a *transit*. The *upward angle* at which the transit is tilted is indicated on the protractor by the point at which weighted string (plumb line) crosses an angle reading on the protractor.

4. Measuring Angles with a Transit (Demonstration and Activity 4-6)

Materials: Homemade transit (see demonstration 3 above), yardstick, sheet of graph paper, pencil, foot ruler, and protractor.

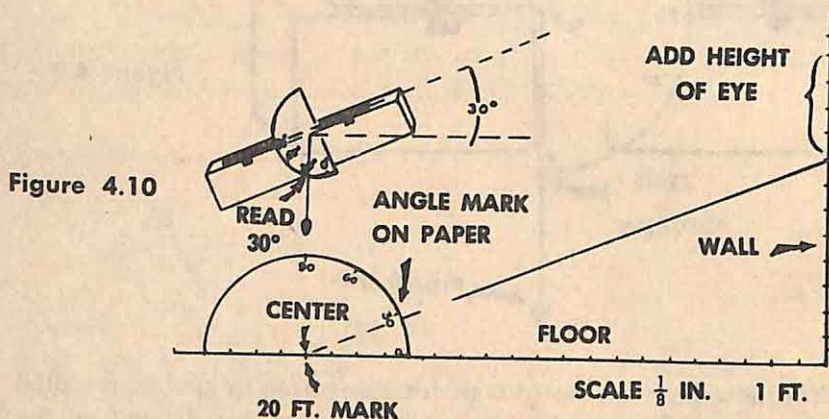
Procedure: Measure a distance of twenty feet from the base of the wall of your classroom. Mark this distance on the floor. Using the transit, sight through the straw to the point where the wall meets the ceiling. Read the angle indicated on the protractor by the thread of the plumb line. Be sure the plumb line has stopped swinging before reading the angle. Two students will be needed for this activity—one to aim the transit and the other to read the angle. Now draw a picture of what you have done so far. Using your ruler and a sheet



of notebook paper, mark off each quarter inch on the right hand edge of the paper and at the bottom as illustrated in Figure 4.10. Each quarter inch will equal one foot for your scale of measurement. The right hand edge of the paper will represent the wall, the height of which is to be measured. The bottom of the paper will represent the floor of the room. Mark off 20 feet on the bottom of the sheet of paper, using the scale one quarter inch equals one foot. This 20 feet will represent the distance measured from the base of the wall to the point where the sighting was taken.

Place the center of another protractor at this 20 foot mark on your paper, making sure that the bottom of the protractor is lined up with the bottom of the paper. Now mark off on your paper the angle which you read on the transit. Remove the protractor from the paper and draw a straight line from the 20 foot mark on your paper through the angle mark until it cuts across the left-hand side of the paper (representing the wall).

Now count the number of quarter inch marks, from bottom to top, on the right hand edge of the paper until you reach the line that cuts across it. Remember each quarter inch equals one foot. Now add to this figure the height of eye of the student that actually took the sighting with the transit. This final figure will give a good estimate of the height of the wall.



Discussion: The children will be able to measure the height of other subjects, too, such as the height of the school flag pole, the school building, and the house they live in. It should be noted that two measurements must be made in order to find the third measurement. The distance from the wall and angle sighting of the top of the wall were necessary to find the height of the wall. If your students have not had experience with using *scales*, you might explain to them that a *scale drawing* changes the size of an object but not its *shape*. A good example of this is similar triangles.

5. Measuring the Rate of Ascent of a Gas Filled Balloon (Activity 4-6)

Materials: Helium- or hydrogen-filled "jumbo" balloon, silk thread, and a stop watch or watch with second hand sweep.

Procedure: Tie one end of a spool of silk thread to a helium filled balloon.

Hold the spool of thread in your hand at floor level and allow the balloon to rise to the ceiling of the room as you slowly unravel the thread. Pull the balloon down to the floor and measure the length of the thread from the floor to the balloon. Pull the balloon to the floor, release it, and measure the time it takes for it to rise freely to the ceiling and strike it. Record this time. Repeat this procedure several times and calculate the average time it takes for the balloon to strike the ceiling. Divide the string length by the average number of seconds it took the balloon to strike the ceiling. This is the same method used to determine mph (distance divided by time).

Discussion: Your answer will be the average rate of ascent of the balloon. Example: If it took the balloon four seconds to rise twelve feet (the height of your ceiling), its rate of ascent would be three feet per second. $4 \frac{3}{12}$. Have the children calculate the height the balloon would rise in 30 seconds, in 60 seconds, 90 seconds, 120 seconds, and so on. Multiply the rate of ascent by the number of seconds. In 30 seconds the balloon would rise 90 feet, in 60 seconds 180 feet, in 90 seconds 270 feet, and in 120 seconds 360 feet. Practice in making such calculations will be of considerable value in the next activity.

6. Using a Transit to Determine the Speed of the Wind (Activity 4-6)

Materials: Helium- or hydrogen-filled "jumbo" size balloon, transit, stop watch, or a watch with a second hand sweep, notebook paper, and a pencil.

Procedure: Four students will be needed to make transit sightings of the weather balloon at the following stations: (a) transit operator—to sight the balloon with the transit; (b) angle reader—to read the angle on the transit protractor, as indicated by the *plumb line*, in a loud, clear voice so that the recorder can hear him; (c) recorder—to record the angle given to him by the angle reader at each thirty second interval as the sightings are being taken; (d) time keeper—to give the ready signal to release the balloon and mark each thirty second interval of time when the sightings should be read by the angle reader. The time keeper's job is to keep his eye on the watch. He should give a "standby" signal (in a loud clear voice) five seconds before a sighting is to be taken. When the second sweep hand of the watch reaches the thirty second mark, he will give the signal "mark." The *standby* signal alerts the transit operator, the angle reader, and the recorder to the fact that a sighting is to be made in five seconds. The *mark* signal is the *command* to the angle reader to read the angle indicated on the transit.

When the data for about four sightings has been recorded, the position of the balloon at each thirty second interval can be plotted.

Construct a graph with a vertical and a horizontal axis as illustrated in Figure 4.11. The vertical axis will represent the height, in fact, which the balloon rises at any thirty second interval. This is calculated from the balloon's rate of ascent, as explained in activity 5 of this section. The scale will be one inch equals 200 feet.

The horizontal axis will represent the horizontal distance which the wind has carried the balloon. This distance is determined by the angle observed

on the transit. The scale for the horizontal axis will be the same as for the vertical axis (one inch equals 200 feet).

Refer to Figure 4.11 to construct the position of the balloon at any given 30 second observation. Using a protractor, construct the observed angle by placing the center of the protractor at the vertex of the horizontal and vertical axes of the graph. Mark this angle on the graph. Then draw a line from the vertex through the observed angle mark. Extend this line until it intersects the horizontal line that indicates the height at which the balloon should be at the time the observation was made. This intersection shows the position of the balloon for that particular observation.

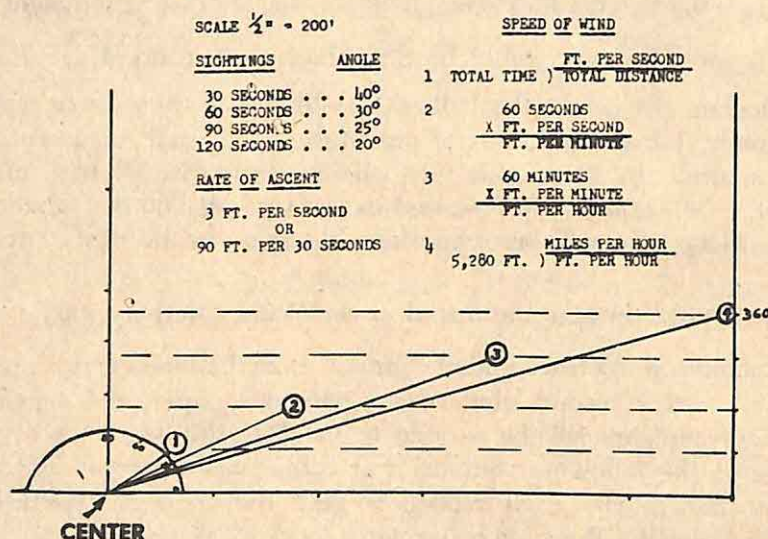


Figure 4.11

Discussion: With the plot constructed, the following information can be obtained:

(a) *The average speed of the wind.* Measure the distance traveled by the balloon *over the ground*, using the horizontal axis of the graph. In the problem illustrated in Figure 4.11 the balloon traveled 1,200 feet in 120 seconds as indicated by position 4 on the plot. This is the *total distance* traveled by the balloon during this time interval. Divide this total distance (1,200 feet) by the total time (120 seconds) to find the number of feet per second that the balloon traveled. To find distance traveled per minute, multiply feet per second by 60 seconds. To find feet per hour, multiply feet per minute by 60 minutes. To find miles per hour, divide feet per hour by 5,280 feet (1 mile). In the case illustrated in Figure 4.11, the wind speed, using four sightings at 30 second intervals, was about 7 m.p.h. Remember, this is the average speed of the wind.

(b) *The speed of the wind between successive positions* can be calculated using *only* the distance the balloon traveled between each sighting. This would also provide the approximate wind speed for various altitudes.

(c) For more advanced studies in working with geometry, *the height and distance of the balloon* could be predicted for *any given angle*. Many other predictions of angles and altitudes may also be made.

This activity has proven to be a very interesting, exciting, and broadening experience for elementary school children. The results have proven most rewarding for the children and the teachers who try it.

Helium gas is recommended in preference to hydrogen gas for filling your balloons as hydrogen is highly explosive. If hydrogen is used, great care should be taken to prevent any sparks and flames. A cylinder of helium or hydrogen can be obtained from a welding supply house or a welding shop located in your area. Many machine shops use helium in their welding process and are usually very cooperative in filling your balloons for you.

7. Determining the Height of the Clouds (Activity 4-6)

Materials: Helium or hydrogen filled balloon and a watch with a second hand sweep or stop watch.

Procedure: Calculate the rate of ascent of the balloon as described in activity No. 5 of this section. Release the balloon out of doors on a day when the cloud cover is low. After releasing the balloon observe the time it takes it to rise and disappear into the base of the clouds.

Discussion: To find the height of the base of the clouds, multiply the rate of ascent of the balloon by the total time it took the balloon to rise from the ground and disappear into the clouds. If the rate of ascent was three feet per second and the total time it took the balloon to rise was 70 seconds, the height of the cloud base is 210 feet.

A study of the types of clouds and their characteristics could be initiated from this activity.

8. Using Gas Filled Balloons to Determine the Direction of the Prevailing Winds (Activity 4-6)

Materials: Helium or hydrogen filled "jumbo" size balloons, string, and post cards.

Procedure: Inflate about 30 "jumbo" size balloons with helium or hydrogen. Attach to each balloon a string approximately one foot in length. Type or write on the back of 30 post cards the following statement: "Our class is making a study of the upper winds. Will the finder of this post card please write the date and place where the balloon was found?" (Leave some space for the date and place to be written on the post card.) "Please drop this card with the information requested in the nearest convenient mail box. Thank you." Sign your name at the bottom of the card. On the front of the post card write your school address. Punch a hole in one corner of the card and tie it to the other end of the string attached to the balloon. Release the balloons in an open area where they will not catch on trees or wires.

Discussion: It is hoped that someone may find one or more of the cards and send it back to your school. The chances of this happening are good, depending, of course, on where you live and how densely populated the surrounding area is. Some schools have received cards back from areas up to three hundred miles away.

Larger plastic balloons, which can sometimes be purchased at army surplus stores, will travel much farther than the "jumbo" size rubber balloons bought at the local five and dime store. After a card is received, have the children locate the place on a map where that balloon was found. Have the children determine the direction the balloon traveled and measure on the map the distance it traveled from the location of their school to the place where it was found. An estimate of the height at which the balloon had to travel to pass over natural barriers may give a clue to the extent of the height of the *prevailing upper winds*.

If you live in an area which is influenced by cyclonic storms, the direction in which the balloon traveled may not be in the direction of the prevailing upper winds, as anticipated. In the event this does happen, obtain the weather maps from the newspaper and check the wind activity for the days during which the balloons were en route. Write to the United States Weather Bureau, Washington 25, D. C., requesting copies of the official weather maps for that period of time. A call to the nearest weather observation station might produce faster results in obtaining the same weather maps. These governmental agencies are very helpful and anxious to be of service.

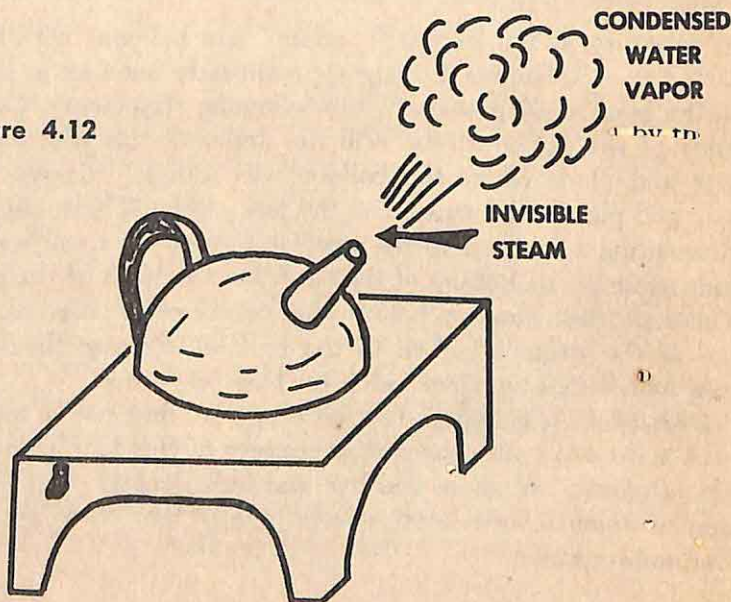
D. CLOUDS AND OUR WEATHER

1. Producing Water Vapor (Demonstration K-6)

Materials: Tea kettle, hot plate, and water.

Procedure: Pour some water into a tea kettle, place it on the burner of a hot plate, and allow it to boil. Observe the spout of the tea kettle as the water boils.

Figure 4.12



Discussion: Two things should be observed—steam from the spout and a cloud of condensed water vapor. The steam is the invisible gas escaping from the spout. The condensed water vapor is the white cloud-like formation just beyond the steam. Actually, the water vapor is steam which has cooled and condensed. The illustration in Figure 4.12 will help you define the margin between the steam and the condensed water vapor. Clouds are made from tiny droplets of condensed water vapor which has escaped into the air. Water vapor can be invisible, too, and yet not be steam. The molecules of water are so small that they cannot be seen. The air around you has water vapor in it, but you cannot always see it.

2. Condensation and Evaporation of Water

Refer to Chapter V, Section C entitled "The Simple Physics and Chemistry of Water," for demonstrations and activities dealing with the understanding of the process of evaporation and condensation.

3. The Clouds Get Their Moisture From the Air Around Us (Demonstration K-6)

Materials: Large jar or large tin can, water, ink, and ice.

Procedure: Half-fill the jar with cold tap water. Pour some ink into the water to color it. Wipe the outside of the jar dry with a cloth. Have one or two children touch the sides of the jar and testify to its dryness. Add enough ice cubes, or snow (if available), to the jar to fill it. Stir the ice and water slowly for several minutes; then have the same two children feel the outside of the jar once again.

Discussion: The children will feel and see moisture on the outside of the jar. Their first reaction to this might be that the water spilled over the side of the jar. If this does occur, have them investigate the color of the water on the outside of the jar and compare it with the ink-colored water inside the jar. The water on the outside will be colorless. The air in the immediate vicinity surrounding the jar was cooled by the ice water. As it cooled, the moisture in it condensed and formed on the outside of the jar. The fact that it was colorless proved that it *did not* come from within the jar but must have come from around the jar. Water vapor can be invisible at times but visible at other times when the tiny droplets of water collect together as they do in clouds.

4. Producing Rain by Condensation (Demonstration K-6)

Materials: Tea kettle, hot plate, metal pan or dish, and water.

Procedure: Boil some water in a tea kettle on a hot plate until a good flow of steam and vapor comes from the spout. Hold a metal pan or a dish above the spewing water vapor at a safe distance for several minutes. Observe the metal pan.

Discussion: The metal pan is cooler than the water vapor. As the water vapor strikes the pan, it also is cooled. As it cools, it condenses forming large drops of water which begin to run off the pan onto the work table or floor.

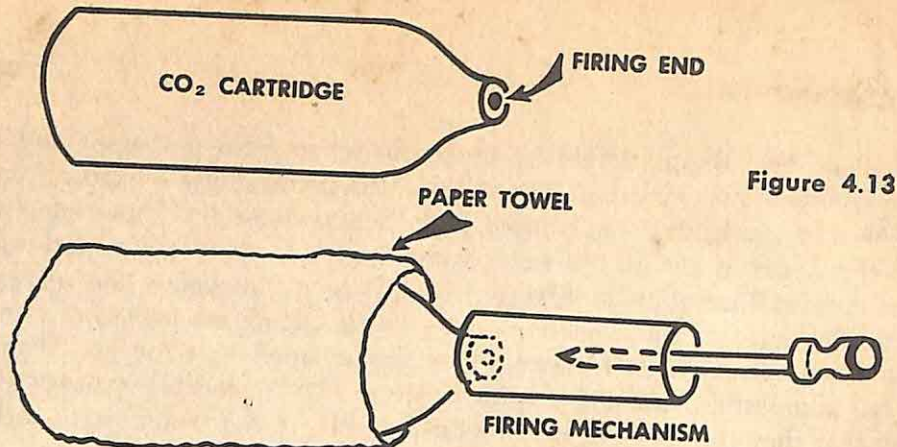


Figure 4.13

The accumulation of the tiny water vapor droplets form larger droplets, which eventually drip from the pan onto the floor. Rain drops form in clouds in much the same manner; however, there are other factors involved which will not be discussed at this time.

5. The Formation of Ice Crystal Clouds (Demonstration 4-6)

Materials: One carbon dioxide cartridge, firing device, and several paper towels.

Procedure: Wrap a carbon dioxide cartridge in some paper towels, leaving the firing end exposed. Hold the cartridge in your hand as illustrated in Figure 4.13 and have one of your students attach the firing mechanism and puncture the cartridge. What happens?

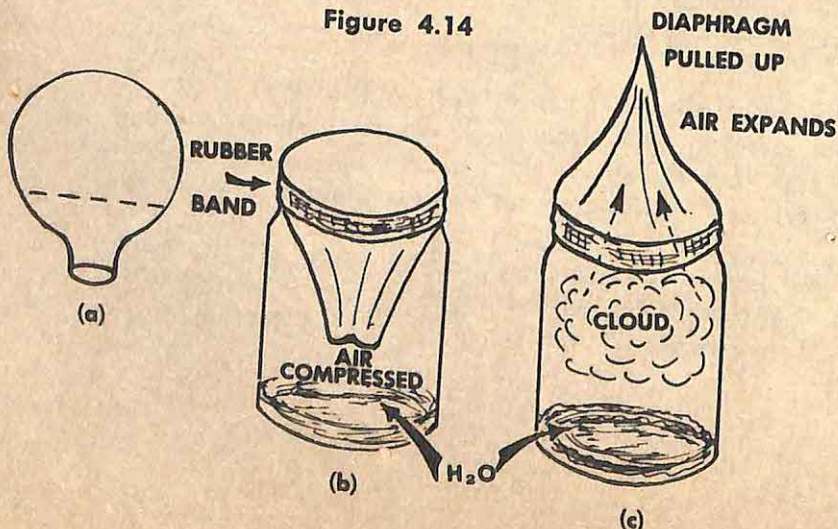
Discussion: The rapid expansion of escaping CO_2 gas is accompanied by a loud hissing noise. As the escaping gas leaves the cartridge, it cools rapidly, so rapidly that it causes the cartridge to cool below the freezing temperature of water. In turn, the air immediately surrounding the outside of the cartridge is also cooled below the freezing temperature of water. The water vapor in this air freezes within a split second, forming tiny ice crystals on the outside of the cartridge.

6. Producing Clouds in a Cloud Chamber

Materials: Wide-mouth gallon jar, large rubber balloon, water, adhesive tape, scissors, and matches.

Procedure: Pour about half a cup of water into the wide-mouth gallon jar.

Figure 4.14



Screw on the lid and allow the jar and water to stand for a few minutes. Cut a rubber diaphragm from a large rubber balloon as illustrated in Figure 4.14(a). Remove the lid and drop a burning match into the jar. Quickly stretch the rubber diaphragm over the mouth of the jar. To ensure that the diaphragm will not slip off the mouth of the jar, tape it firmly to the jar as illustrated in Figure 4.14. Using your fist, force the rubber diaphragm into the jar as illustrated in Figure 4.14(b). Hold the diaphragm in this position for a few seconds: then grasp it in the center between your thumb and forefinger and pull it upward into the position illustrated in Figure 4.14(c). What do you observe inside the jar? Force the diaphragm back into the jar again and observe what happens.

Discussion: The air was compressed inside the jar when the diaphragm was forced into the jar. As the diaphragm was pulled upward, the area inside the jar was increased rapidly. As the area increased, the air inside the jar expanded rapidly. As it expanded, it cooled, causing the water vapor in the air to condense and form a cloud. The water vapor came from the water in the jar. The smoke was used to provide nuclei around which the droplets of water formed. As the diaphragm was forced back into the jar again, the increased pressure caused a rise in temperature in the jar, which can be felt on your hand. The increased temperature was enough to evaporate the water droplets, and the cloud disappeared. Warm air can hold more water vapor than cool air.

7. Dust Particles Help Form Rain Drops (Demonstration 4-6)

Materials: Sugar lump, medicine dropper, glass jar, ink, shallow dish, and water.

Procedure: Mix some ink and water in a small jar. Squeeze a few drops of colored water into a shallow dish. Place the lump of sugar next to and touching the drop of colored water. What happens? Add a few more drops of colored water.

Discussion: The sugar lump absorbs the colored water in much the same way dust particles and smoke particles absorb tiny droplets of water in the clouds. The more water they absorb, the heavier and larger they become until they fall as raindrops.

8. Learning Cloud Formations (Activity 4-6)

INFORMATION ABOUT CLOUD FORMATIONS

Name	Classification	Symbol	Height
cirrus	high	Ci	20,000-40,000 ft.
altostratus	middle	As	8,000-20,000 ft.
stratus	low	St	below 8,000 ft.
fog	low		ground level
cumulus	vertical	Cu	vertical
cumulonimbus	vertical	Cb	development

The clouds described in the above chart are distinct both in appearance and in the way they develop. There are, however, several other types of clouds

which are not as easily separated into readily distinguishable types. Some are combinations of various forms, which make it almost impossible for an inexperienced meteorologist to classify them into any single type of cloud. As the children become more experienced in observing clouds, these cloud formations can be studied in more detail.

E. WEATHER INSTRUMENTS

1. Making a Thermometer (Activity K-6)

Materials: Pint milk bottle, one-hole rubber stopper, glass tubing, water, and ink.

Procedure: Fill a pint milk bottle to the rim of the opening. Press the one-hole rubber stopper into the mouth of the bottle and remove the stopper once again. This will establish the desired height of water in the jar. Pour a few drops of ink into the water to color it. Insert a 12 inch length of glass tubing into the one-hole rubber stopper as illustrated in Figure 4.15. Lubricate the glass tubing with soap before attempting to insert it into the stopper. Insert the one-hole rubber stopper with glass tubing into the mouth of the milk bottle and press it down tightly as illustrated in Figure 4.15. This will force the colored water up the glass tube several inches. Mark the height of the water column with a piece of masking tape. Clasp your hands around the jar for several minutes and observe the height of the water column in the glass tubing. What happens? Place the milk bottle in a pan of cold water and observe the column of water. What happens? Why?

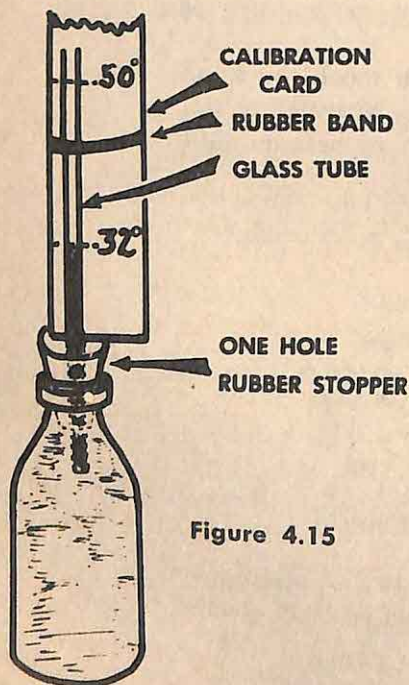


Figure 4.15

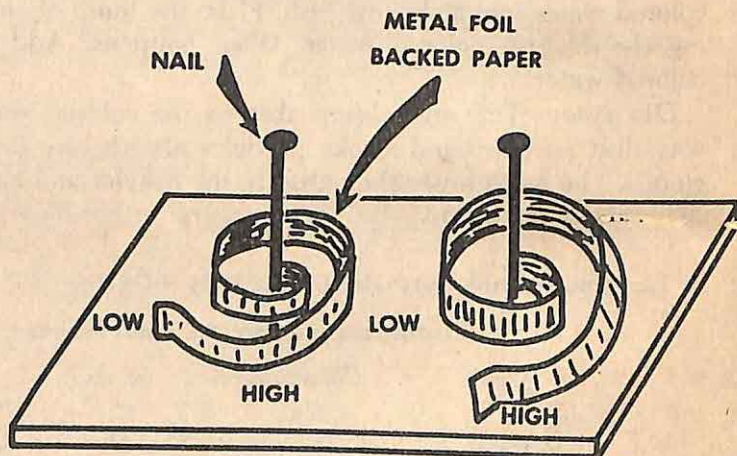


Figure 4.16

Discussion: As the one-hole rubber stopper is pressed into place, the water level rises a few inches up the glass tubing. When the water is heated by the warmth of your hands, it expands (gets bigger) and rises up the glass tubing. When the water is cooled in the pan of cold water, it contracts (gets smaller), and the level of the water drops down the tube. The water reacts to the change in temperature as does an alcohol filled thermometer or a mercury filled thermometer. Alcohol and mercury, however, are more sensitive to temperature changes than water.

The water thermometer can be calibrated by comparing it with an alcohol or mercury thermometer. Place the water thermometer and an alcohol thermometer in the same pan of water. Attach a card to the glass tubing of the water thermometer as illustrated in Figure 4.15. When the colored water in the glass tubing ceases to rise, note the temperature reading in the alcohol thermometer. Mark the height of the water level on the card and write the temperature noted on the alcohol thermometer next to the mark. To calibrate the freezing temperature of water (32°F), place both thermometers in ice water or in crushed ice or snow. Mark the card as before and write the temperature next to the mark.

2. Making a Humidity Indicator with Metal Foil Backed Paper (Activity 4-6)

Materials: Metal foil-backed paper, wooden board, two nails, medicine dropper, and water.

Procedure: Cut two half-inch wide strips of metal foil-backed paper. Chewing gum wrappers and some shiny soap wrappers can be used as a source of this material. Glue one end of each strip of paper to a nail. After the glue dries, roll each strip around the nail to which it is attached, keeping the foil side of the paper facing outward. Drive the nails (with coil) into a board, placing them several inches apart from each other as illustrated in Figure 4.16. Wet each coil of foil-backed paper with a few drops of water from a medicine dropper. What happens?

Discussion: After the coils become wet, they begin to uncoil. The paper side of the coil absorbs the water and attempts to expand. The metal foil, which is glued to the paper, tends to restrict this expansion because of its rigidity and is not affected by the water as the paper is. The force caused by the expanding paper overcomes the rigidity of the metal foil and forces it to *bend* since the water will not cause it to expand. This action tends to straighten out the coil, which causes the loose end of the coil to change position. If the paper is allowed to dry, it will shrink and coil up again.

The action of the metal foil-backed paper makes it an ideal substance for constructing a humidity indicator. When the coil becomes moist, it moves in one direction. When it dries again, it moves in the opposite direction as the paper shrinks. Mark the position of the loose end of the paper when the coil has expanded from the moisture. This will indicate *high* humidity. Mark the position of the loose end of the paper after it has dried and the coil has contracted. This will indicate *low* humidity.

3. Making a Humidity Indicator with Cobalt Chloride and Paper

Materials: Cobalt chloride crystals, shallow pan, water, white paper, and a jar.

Procedure: Dissolve several cobalt chloride crystals in a pint jar. Pour the solution in a shallow pan. Dip several sheets of white paper into the solution and soak them for several minutes. Remove the papers from the solution and allow them to dry. What color is the paper? After they are thoroughly dry, cut them in as many strips as desired to use as humidity indicators. How can these strips be used as humidity indicators?

Discussion: The paper will dry a blue color the same as the blue of the cobalt chloride crystals. As the moisture in the air increases, the blue paper will turn whitish. As the air becomes drier again, the paper will return to a darker shade of blue.

The treated paper can be cut into many interesting designs, such as flowers, dolls, animals, or sails for a sail boat.

Have the children place one indicator out of doors, where it can be observed from inside the classroom, and one in the classroom. Is there ever any difference in the humidity indication shown by the one indoors and the one outdoors at the same time?

4. Making a Sling Psychrometer (Activity 4-6)

Materials: Two thermometers, wire coat hanger, white shoe lace, two eye hooks, and a board $\frac{1}{2}$ inch by $4\frac{1}{2}$ inches by 8 inches.

Procedure: Construct a sling psychrometer as illustrated in Figure 4.17. Slip a length of shoe lace over one thermometer bulb and moisten it. After moistening the shoe lace on the wet bulb thermometer, grasp the handle and swing the psychrometer around the shaft in a circular motion until the temperature on the wet bulb thermometer stops falling. Check it every few seconds. Stop the swinging and record the temperature of both thermometers. Which one reads lowest? Why?

Discussion: The wet bulb will always read less than, or the same as, the dry bulb. It will never read more than the dry bulb. The spinning of the psychrometer causes a wind effect on the thermometers. The wind hastens the evaporation of the water on the shoe lace wrapped around the bulb of the thermometer. Evaporation is a cooling process which influences the temperature indication on the wet bulb thermometer. The faster the evaporation, the lower the temperature around the wet bulb. Find the difference between the two readings and enter on the relative humidity chart, which will be discussed in activity No. 6 of this section.

5. Another Type of Sling Psychrometer (Activity 4-6)

Materials: Two identical thermometers, rubber bands, water, length of string, and a white shoe lace.

Procedure: Construct a sling psychrometer by fastening the two thermome-

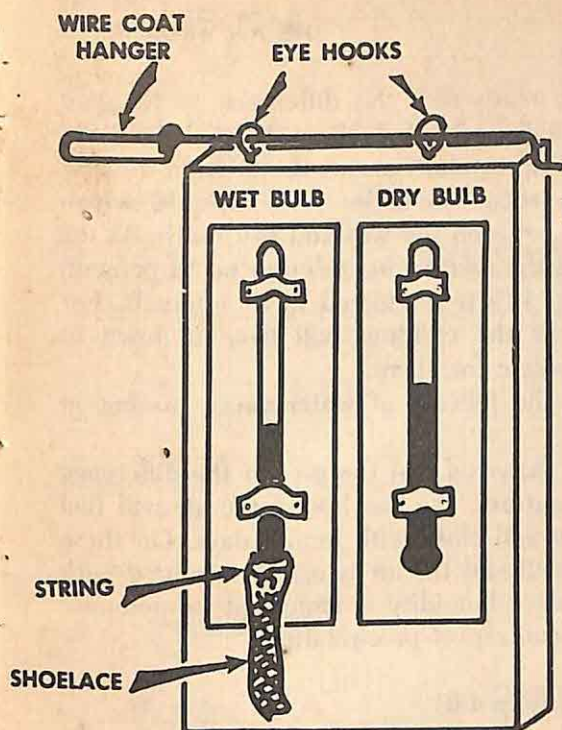


Figure 4.17

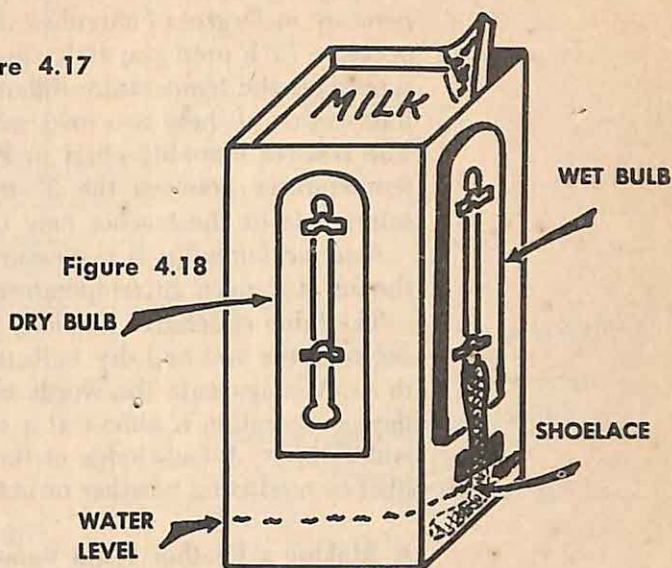


Figure 4.18

ters back to back with rubber bands. Slip a length of shoe lace over one thermometer bulb and moisten it. Tie a two-foot length of string through the holes on the ends of the thermometers. This will be used to swing the psychrometer.

Discussion: The same as for activity No. 4 of this section.

6. Constructing a Psychrometer (Activity 4-6)

Materials: Two thermometers, white shoe lace, milk carton, rubber bands, and water.

Procedure: Construct a psychrometer as illustrated in Figure 4.18. With rubber bands mount a wet bulb thermometer on one side of an empty milk carton and a dry bulb thermometer on an adjacent side of the same milk carton. Cut a small hole near the bottom of the milk carton just below the wet bulb thermometer and insert the shoe lace. Pour some water in the milk carton to keep the shoe lace moist.

Discussion: The principle of operation of the wet and dry bulbs of this psychrometer is the same as that for the sling psychrometer with exception that we do not *sling* it. Instead, it should remain stationary while you fan it with a sheet of paper until the temperature of the wet bulb stops dropping.

7. Reading and Using a Relative Humidity Table (Activity 4-6)

Calculating the relative humidity for any given day is a simple task if a psychrometer and a relative humidity table are available. As an example of how to determine relative humidity, refer to the *Relative Humidity Table* illustrated in Figure 4.19. If the *dry* bulb of your psychrometer read 75°F

under the column and the wet bulb reads 65° , the difference in the two readings would be 10 degrees. Find 75°F under the column labeled *Air Temperature in Degrees Fahrenheit*. Move horizontally across the table in the row opposite 75°F until you arrive in the vertical row under the number 10, which represents the temperature difference between the wet and dry bulbs. At the intersection of these two rows we find the *relative humidity* to be 58 percent. The relative humidity chart in Figure 4.19 is graduated in 5° intervals. For temperatures between the 5° intervals the children will have to learn to interpolate or the teacher may interpolate for them.

Relative humidity is a measure of the percent of water vapor present in the air at a given air temperature.

The table of relative humidity also shows us that the greater the difference between the wet and dry bulb temperatures, the less humid the air will feel to us. We associate the words *muggy* and *close* with humid days. On these days evaporation is almost at a standstill and the air is nearly *saturated* with water vapor. A knowledge of the relative humidity is important to meteorologists in predicting whether or not we can expect precipitation.

8. Making a Feather Wind Vane (Activity 4-6)

Materials: Cork, plastic oil can cap, headless finishing nail, small wooden block, and a tail feather.

Procedure: Construct a *weather vane* as illustrated in Figure 4.20. Bore in the wide end of the cork a hole large enough to fit a plastic cap from a "3-in-One" oil can or squeeze bottle glue pot. Insert the cap in the hole in the cork so that it is three-fourths of the way into the cork. The cap will act as a *bearing* surface for the headless finishing nail upon which the wind vane will spin freely. Bore a hole across the narrow end of the cork and insert a tail or wing feather of a bird. The feathers from turkeys, pigeons, and chickens work well. A feather from a feather duster is excellent too. With a sheet of sand paper sand to a smooth point the end of the finishing nail on which the plastic cap bearing is to be placed. This will reduce the friction between the plastic cap and the nail. Drive the headless finishing nail into the board and sand smooth any burrs which may have resulted from its being struck by the hammer. Mount the cork and feather on the end of the nail. Mark the block of wood with letters "N," "E," "S" and "W" to signify compass directions.

Discussion: This weather vane is portable and easy to set up. Locate North and point the "N" painted on the block of wood in that direction. The wind vane will point in the direction *from which* the wind is blowing. If it is pointing north, then the wind is blowing from north to south.

9. Using a Mirror to Tell Direction of the Wind (Activity 4-6)

Materials: Pocket mirror and a crayon.

Procedure: Mark the four compass directions on the pocket mirror, as illustrated in Figure 4.21. Place the mirror on the ground with the compass direction facing the correct way. Stand above the mirror but slightly to one side of it and observe the reflection of the clouds.

RELATIVE HUMIDITY IN PER CENT

Air Temp., °F.		DIFFERENCE BETWEEN WET AND DRY BULB, °F																																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	
0	67	33	1																																		
5	73	48	26																																		
10	79	56	34	13																																	
15	85	64	46	29	11																																
20	91	73	55	40	25	12																															
25	97	81	67	59	37	25	12	1																													
30	103	88	74	67	58	46	36	28	16	6																											
35	109	95	82	75	66	55	45	36	27	10	2																										
40	115	102	90	83	74	65	55	45	37	28	15	7																									
45	121	109	98	91	82	73	64	57	51	44	33	21	25	18	12	6																					
50	127	117	108	101	92	83	75	68	62	56	49	43	38	32	27	21	16	10	5																		
55	133	125	118	111	103	94	87	80	74	68	63	58	53	48	43	39	34	29	24	19	11	9	5														
60	139	133	127	121	115	109	103	97	92	87	82	77	72	67	62	58	54	50	46	42	38	34	30	27	23	19	15	11	7	3	1						
65	145	141	136	131	126	121	116	111	106	101	96	91	86	81	76	72	68	64	60	56	52	48	44	40	36	32	28	24	20	16	12	8	5	2			
70	151	148	144	140	136	132	128	124	120	116	112	108	104	100	96	92	88	84	80	76	72	68	64	60	56	52	48	44	40	36	32	28	24	20	16	12	
75	157	155	152	149	146	143	140	137	134	131	128	125	122	119	116	113	110	107	104	101	98	95	92	89	86	83	80	76	72	68	64	60	56	52	48	44	
80	163	162	160	158	156	154	152	150	148	146	144	142	140	138	136	134	132	130	128	126	124	122	120	118	116	114	112	110	108	106	104	102	100	98	96	94	
85	169	169	168	166	165	164	162	161	160	158	157	156	154	153	151	150	148	147	145	144	142	141	139	138	136	135	133	132	130	128	126	124	122	120	118	116	
90	175	176	176	175	174	173	172	171	170	169	168	167	166	164	163	162	160	159	158	156	155	154	152	151	149	148	146	145	143	142	140	138	136	134	132	130	128
95	181	183	183	183	182	181	180	179	178	177	176	175	174	173	172	171	170	169	168	166	165	164	162	161	160	158	157	155	154	152	150	148	146	144	142	140	138
100	187	190	190	190	189	188	187	186	185	184	183	182	181	180	179	178	177	176	175	174	173	172	171	170	169	168	166	165	163	162	160	158	156	154	152	150	148
105	193	197	197	197	196	195	194	193	192	191	190	189	188	187	186	185	184	183	182	181	180	179	178	177	176	175	174	173	172	171	170	169	168	167	166	165	164
110	199	204	204	204	203	202	201	200	199	198	197	196	195	194	193	192	191	190	189	188	187	186	185	184	183	182	181	180	179	178	177	176	175	174	173	172	171
115	205	211	211	211	210	209	208	207	206	205	204	203	202	201	200	199	198	197	196	195	194	193	192	191	190	189	188	187	186	185	184	183	182	181	180	179	178
120	211	218	218	218	217	216	215	214	213	212	211	210	209	208	207	206	205	204	203	202	201	200	199	198	197	196	195	194	193	192	191	190	189	188	187	186	185
125	217	225	225	225	224	223	222	221	220	219	218	217	216	215	214	213	212	211	210	209	208	207	206	205	204	203	202	201	200	199	198	197	196	195	194	193	192
130	223	232	232	232	231	230	229	228	227	226	225	224	223	222	221	220	219	218	217	216	215	214	213	212	211	210	209	208	207	206	205	204	203	202	201	200	199
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140	235	246	246	246	245	244	243	242	241	240	239	238	237	236	235	234	233	232	231	230	229	228	227	226	225	224	223	222	221	220	219	218	217	216	215	214	213
145	241	253	253	253	252	251	250	249	248	247	246	245	244	243	242	241	240	239	238	237	236	235	234	233	232	231	230	229	228	227	226	225	224	223	222	221	220
150	247	260	260	260	259	258	257	256	255	254	253	252	251	250	249	248	247	246	245	244	243	242	241	240	239	238	237	236	235	234	233	232	231	230	229	228	227
155	253	267	267	267	266	265	264	263	262	261	260	259	258	257	256	255	254	253	252	251	250	249	248	247	246	245	244	243	242	241	240	239	238	237	236	235	234
160	259	274	274	274	273	272	271	270	269	268	267	266	265	264	263	262	261	260	259	258	257	256	255	254	253	252	251	250	249	248	247	246	245	244	243	242	241
165	265	281	281	281	280	279	278	277	276	275	274	273	272	271	270	269	268	267	266	265	264	263	262	261	260	259	258	257	256	255	254	253	252	251	250	249	248
170	271	288	288	288	287	286	285	284	283	282	281	280	279	278	277	276	275	274	273	272	271	270	269	268	267	266	265	264	263	262	261	260	259	258	257	256	255
175	277	295	295	295	294	293	292	291	290	289	288	287	286	285	284	283	282	281	280	279	278	277	276	275	274	273	272	271	270	269	268	267	266	265	264	263	262
180	283	302	302	302	301	300	299	298	297	296	295	294	293	292	291	290	289	288	287	286	285	284	283	282	281	280	279	278	277	276	275	274	273	272	271	270	269
185	289	309	309	309	308	307	306	305	304	303	302	301	300	299	298	297	296	295	294	293	292	291	290	289	288	287	286	285	284	283	282	281	280	279	278	277	276
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215	325	351	351	351	350	349	348	347	346	345	344	343	342	341	340	339	338	337	336																		

Discussion: From the reflection of the clouds we can detect the direction in which they are moving as they are being blown by the wind. The movement of the clouds can show us the direction from which the wind is blowing.

10. Making an Aneroid Barometer (Activity 4-6)

Materials: Glass jar, rubber balloon, adhesive tape, soda straw, and sheet of cardboard.

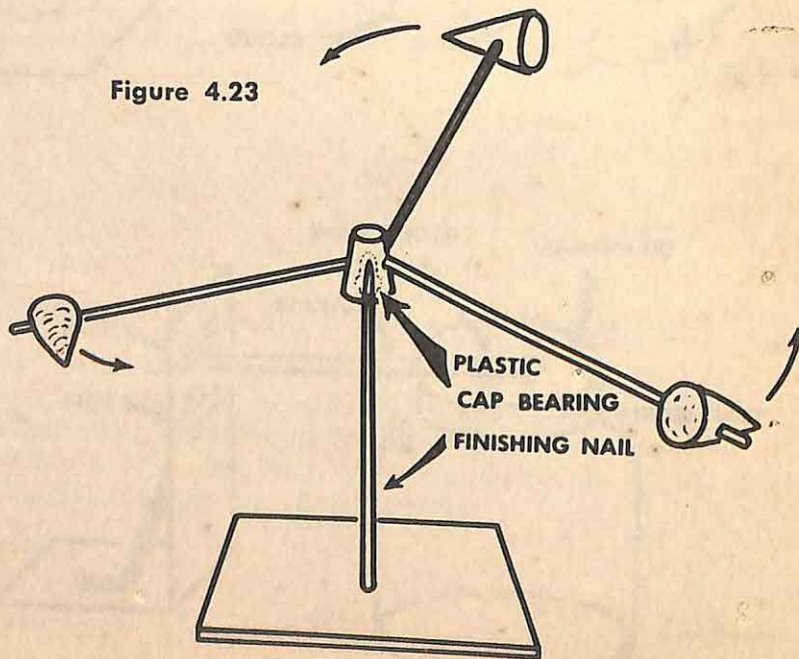
Procedure: Cut a piece of rubber from a balloon and stretch it across the mouth of a jar. Tape the edges of the rubber diaphragm to the jar to hold it tight. Glue a soda straw to the center of the rubber diaphragm in a horizontal position. The straw should be pointing at a sheet of cardboard which is a few inches taller than the jar and stands erect as illustrated in Figure 4.22.

Discussion: The aneroid barometer operates with the change in atmospheric pressure. The change in weight of the air on the rubber diaphragm will move it up or down. This movement will be amplified by the movement of the straw. As the air pressure rises, the free end of the straw will rise. If the air pressure decreases, the free end of the straw will drop. Calibration lines on the cardboard will indicate these changes in atmospheric pressure. Keep this barometer away from excessive heat or cold. The air inside will heat up and expand, causing the rubber diaphragm to expand too and give a false reading. If the air inside cools too much, it will cause the air to contract, and a false indication will again result.

11. Making an Anemometer (Activity 4-6)

Materials: Cork, plastic oil can cap, headless finishing nail, wooden block, three conic-shaped cups, and three throat swab sticks.

Procedure: A plastic cap and a cork make an excellent bearing holder for mounting the arms of an anemometer as illustrated in Figure 4.20 (Making a Wind Vane). Bore three holes at an equal distance apart into the side of the cork and insert a throat swab stick in each hole as illustrated in Figure 4.23.



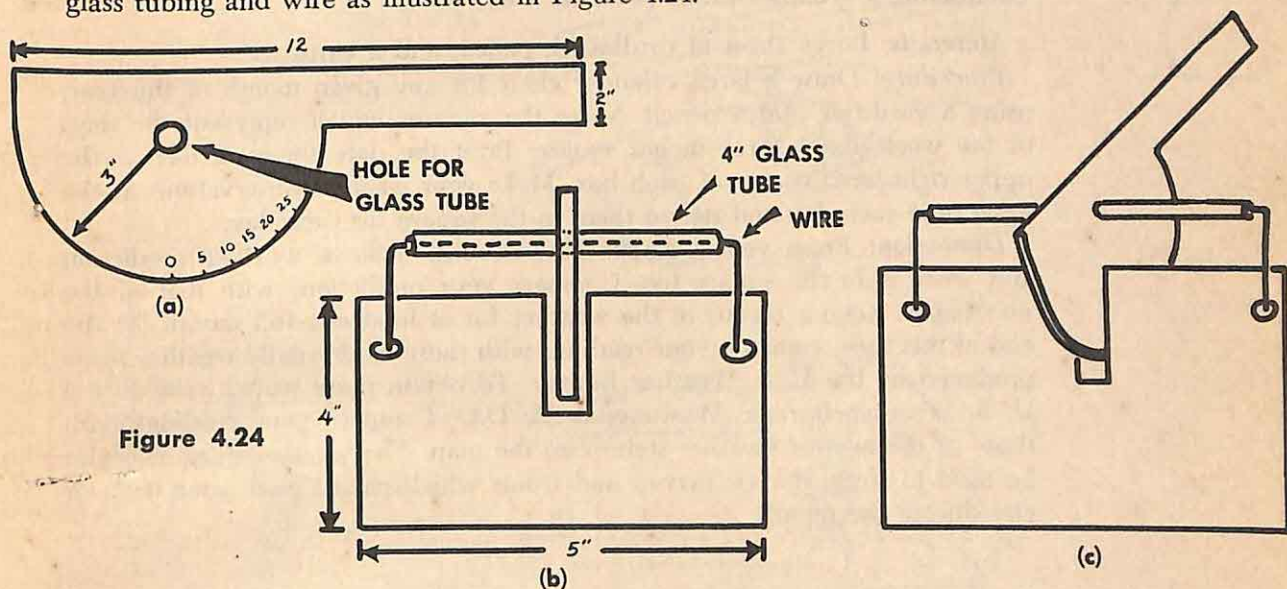
Mount one conic shaped paper cup at the end of each stick for wind cups. Paint one wind cup black. With a sheet of sand paper sand smooth the end of the finishing nail on which the plastic cap bearing is to be placed. This will reduce friction between the plastic cap and the nail. Drive the nail into the board and sand smooth any burrs which may have resulted from its being struck by the hammer. Mount the anemometer on the end of the nail.

Discussion: When placed outdoors, the cups will catch the wind and spin smoothly. To measure the speed of the wind, however, some calibrations must be made first. On a calm day hold your anemometer out the window of a car and count the number of turns your anemometer makes in a fifteen or thirty second interval of time for any given speed of the moving car. Counting the number of turns is made easy by watching the cup you painted black. If you calibrate the number of turns for speeds of 5 to 25 m.p.h. at five mile an hour intervals, this should be sufficient for your use.

12. Another Type of Anemometer (Activity 4-6)

Materials: Sheet of cardboard, 4 inch length of glass tubing, and wire.

Procedure: Cut a cardboard holder and a wind plate and assemble with glass tubing and wire as illustrated in Figure 4.24.



Discussion: This anemometer operates when the force of the wind pushes against the wind plate. To calibrate this instrument, hold the holder in your hand in a horizontal position. The wind plate will hang in a vertical position perpendicular to the holder. In this position the wind plate will indicate zero wind speed. Choose a calm day and hold the instrument out the window of a car with the wind plate end of the holder pointing in the direction of the forward motion of the car. Have the driver accelerate to 5 m.p.h., then 10 m.p.h., 15 m.p.h., etc. Mark the position of the wind plate on the holder at each 5 m.p.h. interval. With your anemometer calibrated, measuring the speed of

the wind is simple. Face the direction *from which* the wind is blowing and expose the wind plate to the wind holding the holder in the horizontal plane.

13. Making a Rain Gauge (Activity 4-6)

Materials: A four inch diameter can, a four inch diameter funnel, and a foot ruler.

Procedure: Place the four inch diameter funnel inside the four inch diameter can small end down. Place the can and funnel out of doors in an open area where the rain will fall into the can through the funnel.

Discussion: Immediately after a rainfall, carefully remove the funnel from the can and dip the end of a foot ruler into the water. Be sure you hold the ruler in as near a vertical position as possible in order to get the most accurate reading. Remove the ruler and read the amount of rainfall in inches as indicated by the wet mark on the ruler. The funnel used with this rain gauge acts as a cover over the can to prevent rapid evaporation of water from the can. No calibrations are necessary with this type of rain gauge. The accuracy of the measurement is solely dependent on the person making the measurement.

14. Making a Weather Chart (Activity 4-6)

Materials: Large sheet of cardboard, pencil, and a yardstick.

Procedure: Draw a large calendar chart for any given month of the year, using a yardstick and a pencil. Make the squares which represent the days of the week about three inches square. Print the date for each day in the upper right-hand corner of each box. Make your weather observations at the same time each day and record them in the square for each day.

Discussion: From your weather observations, make a weather prediction and write it in the square too. Compare your predictions with that of the newspaper. Keep a record of the weather for at least one full month. At the end of this time, compare your readings with those on the daily weather maps produced by the U. S. Weather Bureau. To obtain these maps, write to the U. S. Weather Bureau, Washington 25, D.C. Compare your readings with those of the nearest weather station on the map. The weather maps can also be used to study the air masses and fronts which passed over your town or city during the month.

F. AIR AND THE AIRPLANE

1. Kite Effect on an Airplane (Activity 4-6)

Materials: Sheet of notebook paper.

Procedure: Hold the sheet of notebook paper as illustrated in Figure 4.25(a) and push it through the air. What happens to the paper? Now hold the sheet of paper as illustrated in Figure 4.25(b) and pull it through the air. What happens to the paper?

Discussion: As the sheet of paper is pushed or pulled through the air, the

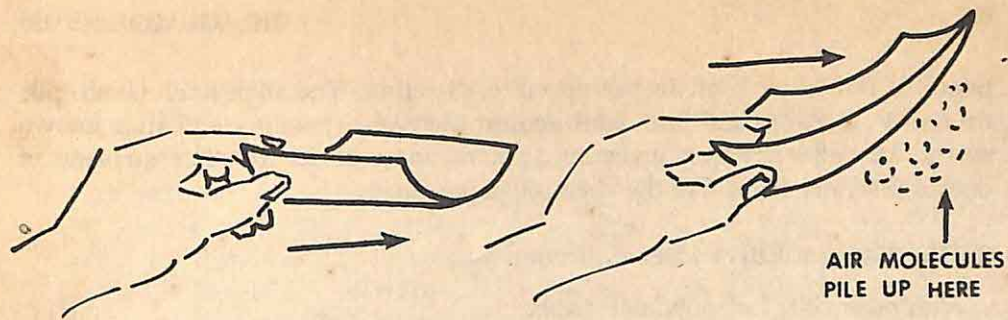


Figure 4.25

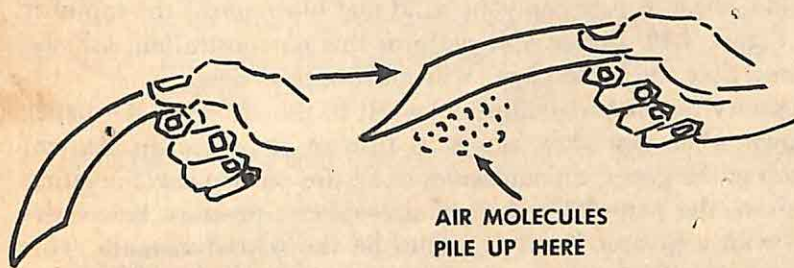


Figure 4.26

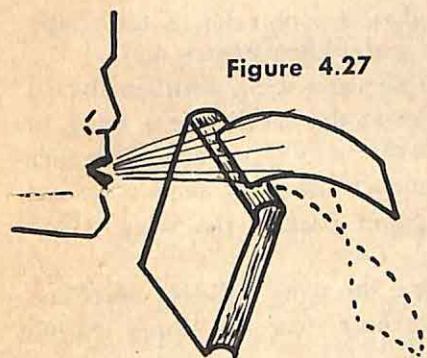
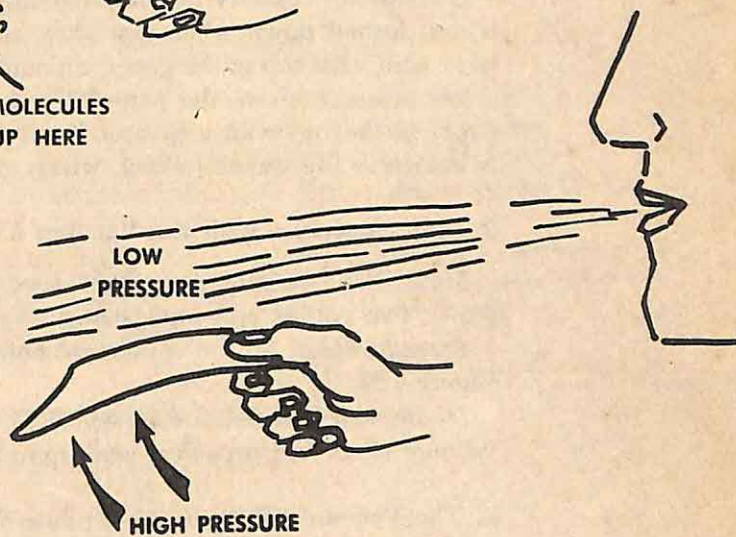
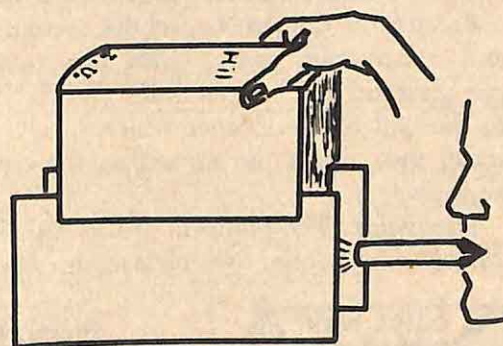
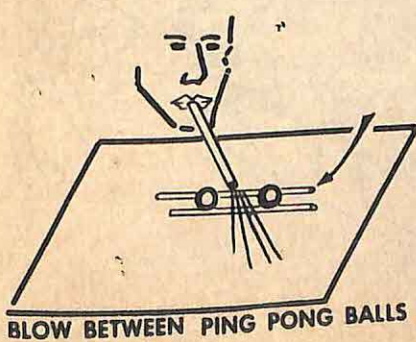


Figure 4.27

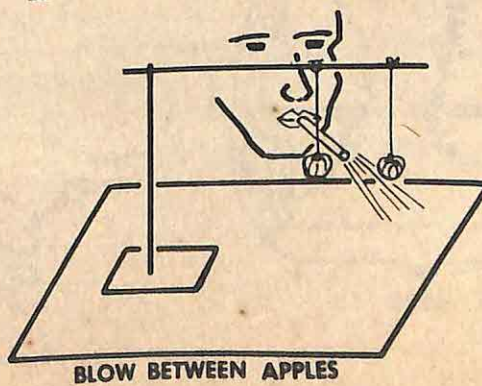
BLOW ACROSS TOP OF PAPER



BLOW BETWEEN SHEETS OF PAPER



BLOW BETWEEN PING PONG BALLS



BLOW BETWEEN APPLES

paper is forced to bend in the opposite direction. The molecules of air pile up under the paper and push back against the paper, bending it. This is known as the *kite effect*, which gives an airplane some of its lift. The airplane of course does not bend like the sheet of paper does.

2. The Vacuum Effect (Demonstration 4-6)

Materials: Sheet of notebook paper.

Procedure: Hold a sheet of paper in your hand and blow across the top of it as illustrated in Figure 4.26. Before you perform this demonstration, ask the children which way they think the paper will move—up or down.

Discussion: Contrary to what may appear logical to the children, the paper is not pushed down when you blow across it. Instead, it moves up. As you blow across the top of the paper, the molecules of air are pushed aside creating a low pressure above the paper. The higher atmospheric pressure below the paper pushes up with a greater force, trying to fill the partial vacuum. This is known as the vacuum effect, which gives an airplane most of its lift.

3. More Activities with the Vacuum Effect (Activity 4-6)

Materials: Two ping pong balls, several straws, three books, three sheets of paper, two apples, and some string.

Procedure: Set up the equipment and follow the directions as illustrated in Figure 4.27.

Discussion: These activities will help establish a good understanding of the vacuum effect and provide a lead up to the study of the airplane wing.

4. The Vacuum Effect of an Airplane Wing (Demonstration 4-6)

Materials: Cardboard, construction paper, glue, a foot ruler, a tank type vacuum cleaner, adhesive tape, and a balance scale. (See Figure 4.27a.)

Procedure: Construct a model section of an airplane wing with cardboard and construction paper. Using tape, attach the model section of a wing to one platform of a balance scale. Switch the hose of a tank type vacuum cleaner to the end of the cleaner which blows air. Balance the wing section on the scale; then direct the air across the curved upper part of the wing. What happens?

Discussion: The platform of the scale to which the wing is taped rises. The strong wind caused by the vacuum cleaner rushing over the upper curved

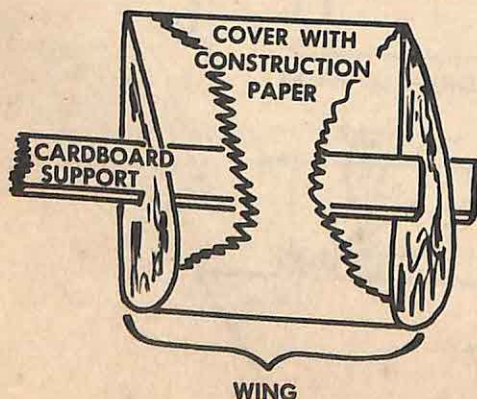
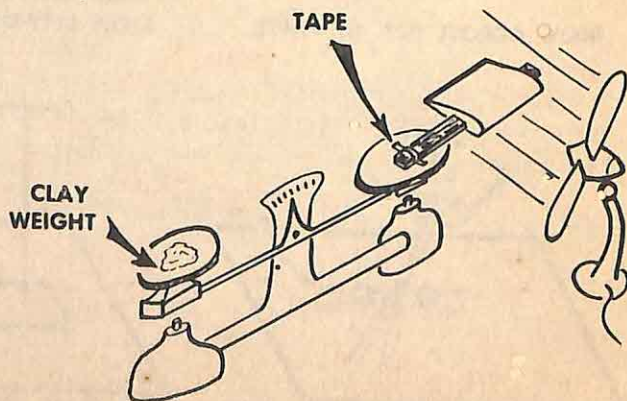


Figure 4.27a



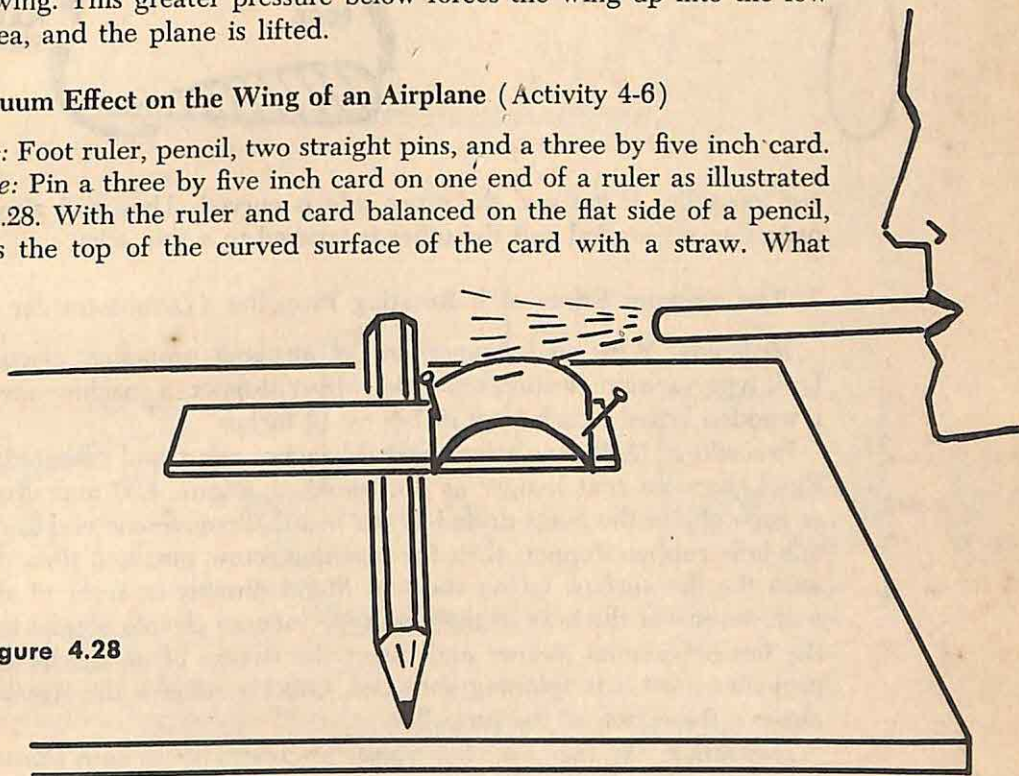
surface of wing creates a low pressure area above the wing. The stronger air pressure below the wing pushes it up in an attempt to fill the partial vacuum. The upper surface of the wing is intentionally designed with a greater curvature, and the air passing over it must travel a greater distance than must the air flowing across the flat under-surface. If the air above the wing must travel a greater distance, then it must travel faster. As it travels faster, more molecules are displaced, creating a low pressure area above the wing. The air moving across the flat bottom surface of the wing is not moving as fast; hence it displaces fewer molecules of air, giving it a higher pressure than the air above the wing. This greater pressure below forces the wing up into the low pressure area, and the plane is lifted.

5. The Vacuum Effect on the Wing of an Airplane (Activity 4-6)

Materials: Foot ruler, pencil, two straight pins, and a three by five inch card.

Procedure: Pin a three by five inch card on one end of a ruler as illustrated in Figure 4.28. With the ruler and card balanced on the flat side of a pencil, blow across the top of the curved surface of the card with a straw. What happens?

Figure 4.28



Discussion: The vacuum effect caused by the rushing air over the curved surface of the card causes the ruler to rise. Again we have a low pressure area above the wing and a high pressure area below the wing forcing it up. The top surface of a wing of an airplane serves the same purpose.

6. Comparing the Shape of a Propeller and a Wing (Demonstration 4-6)

Materials: Model airplane wing and propeller.

Procedure: Compare the cross section view of a model airplane wing and a propeller. Refer to Figure 4.29 for details. How are they alike?

Discussion: The children will discover that the cross section of a wing and a propeller are almost identical. They will notice that one side of the wing

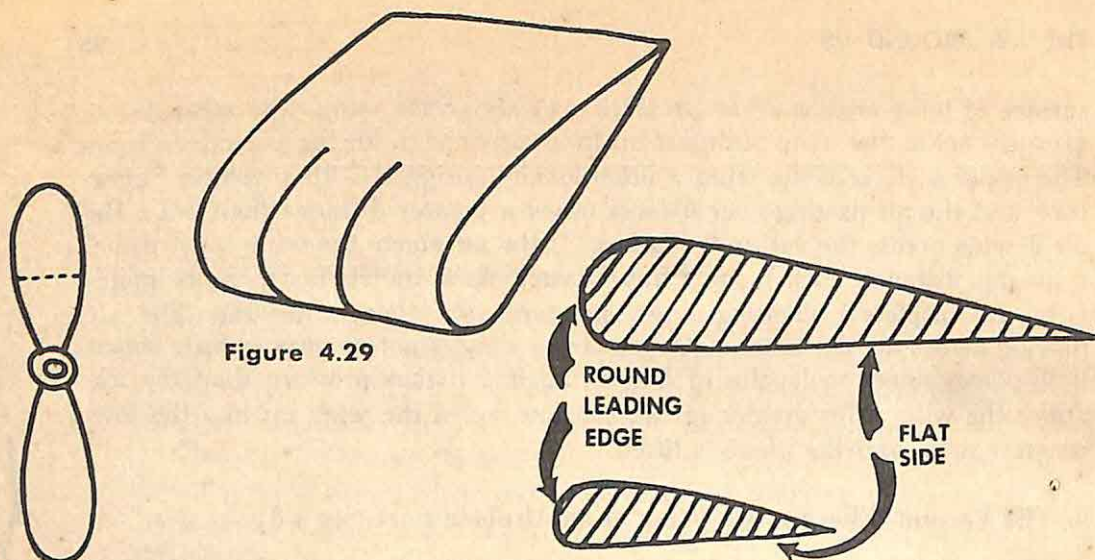


Figure 4.29

and propeller is flat and the other side is curved. They will also notice that one edge is rounded and the other is tapered to a thin edge.

7. The Vacuum Effect of a Rotating Propeller (Demonstration 4-6)

Materials: Wire coat hanger, model airplane propeller, electric fan or a tank type vacuum cleaner, one-hole rubber stopper, a machine screw nut, and a wooden board 1 inch by 6 inches by 18 inches.

Procedure: Drill two holes about 12 inches apart and centered in a board. Bend the wire coat hanger as illustrated in Figure 4.30 and insert the ends in each one of the holes drilled in the board. Remove one end and slip on the one-hole rubber stopper, then the machine screw nut, and then the propeller with the flat surface facing the nut. Stand directly in front of the propeller with the fan or the hose of the tank type vacuum cleaner rigged to blow. Start the fan or vacuum cleaner and direct the stream of air at the center of the propeller until it is spinning very fast. Quickly remove the stream of air and observe the action of the propeller.

Discussion: As the propeller spins, it creates a vacuum effect across the front curved surface of the wing. When the force of the air from the fan is removed, the propeller moves forward very rapidly. The low pressure area created in front of the propeller causes the high pressure air behind the propeller to push the propeller forward. A fast spinning propeller on an airplane causes the propeller and the plane attached to it to be pushed forward. A propeller acts in much the same way as a wing does. Because it does, it is sometimes referred to as a *rotating wing*.

8. Why Wings Are Streamlined (Demonstration 4-6)

Materials: Candle, matches, and a sheet of cardboard.

Procedure: To demonstrate the effect of a flat leading edge of a wing, refer to Figure 4.8 of Section C, "The Wind and Our Weather." To demonstrate the effect of a rounded leading edge, construct a model section of a

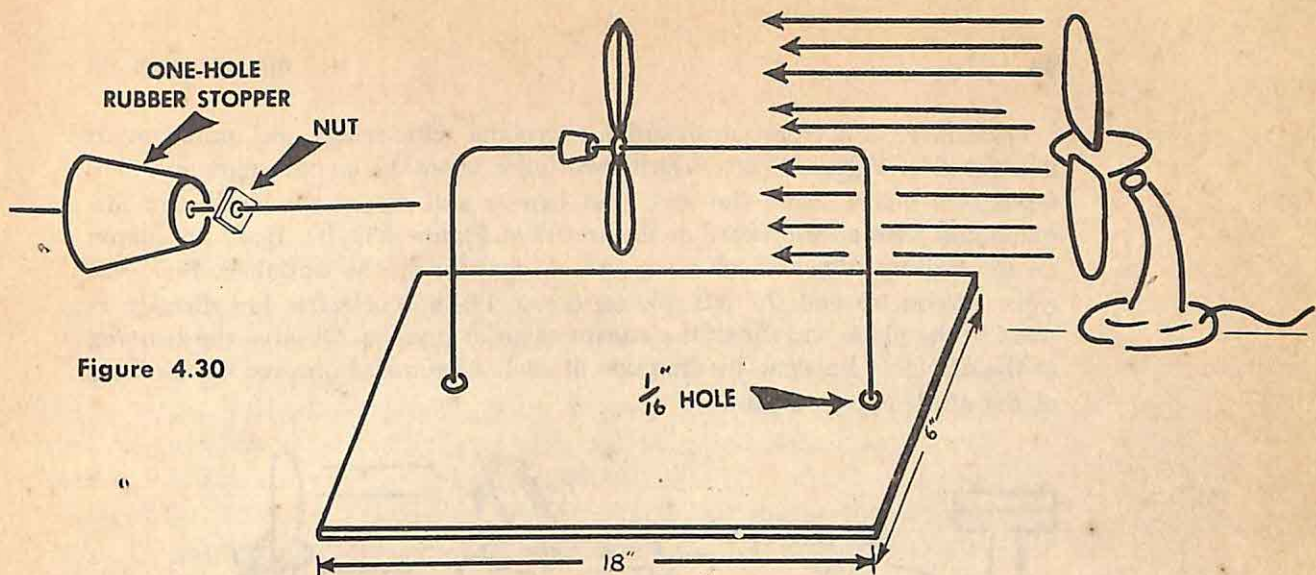


Figure 4.30

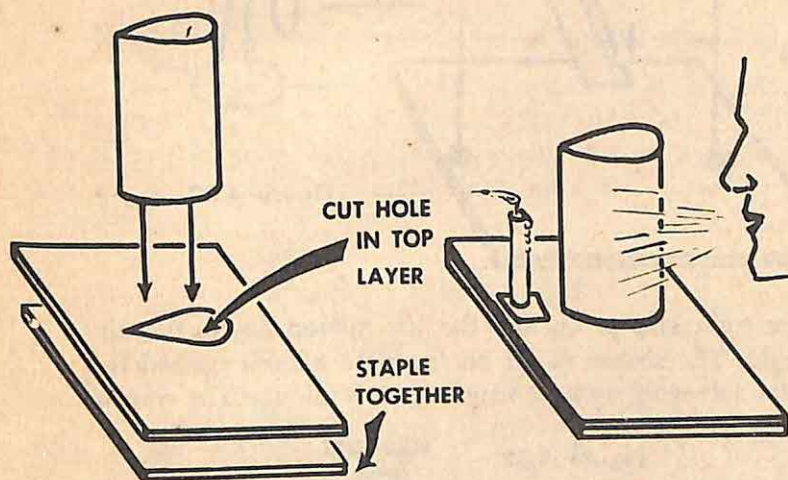
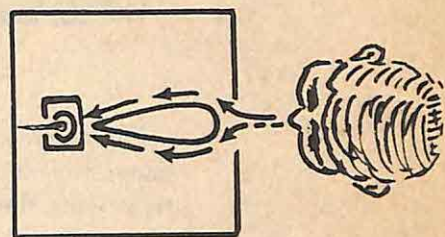


Figure 4.31



wing as illustrated in Figure 4.31. Place a candle behind the trailing edge and blow gently against the rounded leading edge. Observe the direction in which the flame is blown.

Discussion: A stream of air that strikes a flat surface causes eddy currents on the other side. The flame on the other side of the flat surface is blown toward the card, indicating a turbulence of air currents. This turbulence is undesirable for flight. It causes excessive *drag*, which slows down the airplane and reduces the lift effect created by the wing. With a round leading edge of a wing, the air flows over the wing smoothly with little or no turbulence. The candle flame behind the tapered trailing edge indicated a smooth flow of air in the same direction from which it was coming.

Investigate the wings of a real airplane and that of a paper covered model.

9. The Aileron Action of an Airplane (Demonstration 4-6)

Materials: Sheet of cardboard, wire coat hanger, wooden board 1 inch by 6 inches by 18 inches, and electric fan.

Procedure: Cut from cardboard an airplane with wings and stabilizer as illustrated in Figure 4.32(a). Drill two holes about 12 inches apart and centered in a board. Bend the wire coat hanger and mount the cardboard airplane and wire on the board as illustrated in Figure 4.32(b). Bend an aileron on the trailing edge of each wing and an elevator on the stabilizer. Bend the right aileron up and the left aileron down. Place an electric fan directly in front of the plane and direct the stream of air at its nose. Observe the *banking* of the airplane. Reverse the direction of each aileron and observe the *banking* of the airplane once again.

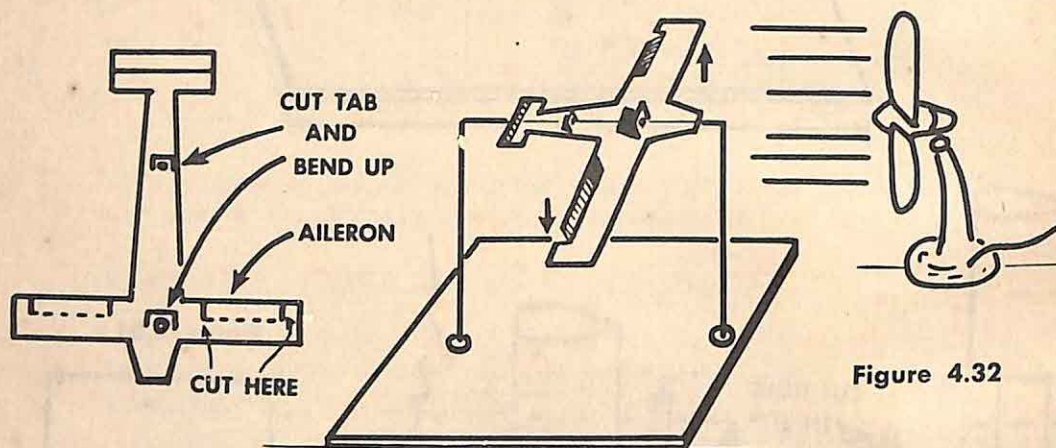


Figure 4.32

Discussion: With the right aileron up and the left aileron down, the airplane *banked* to its right. The stream of air on the right aileron pushed the right wing down and the left wing up as it struck the left aileron. The reverse

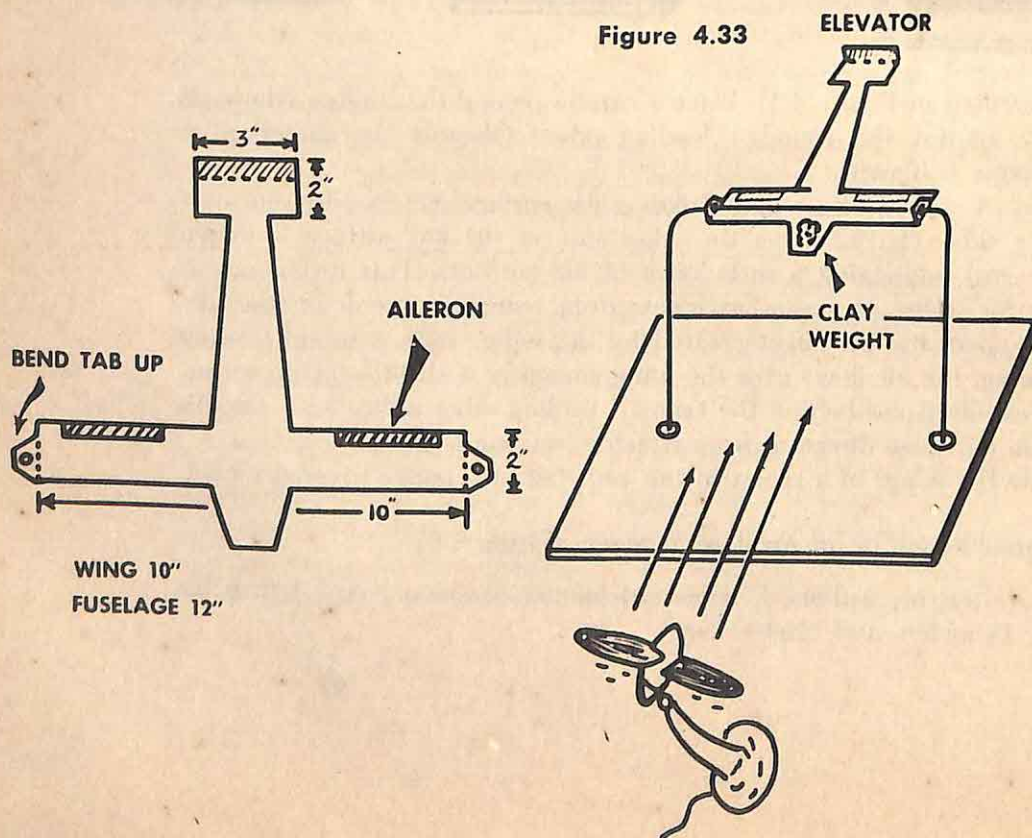


Figure 4.33

action occurred when the position of each aileron was reversed. The net effect of the ailerons is to tilt the wings of the airplane and cause it to turn left or right.

10. The Elevator Action of the Airplane

Materials: The same as for demonstration 10.

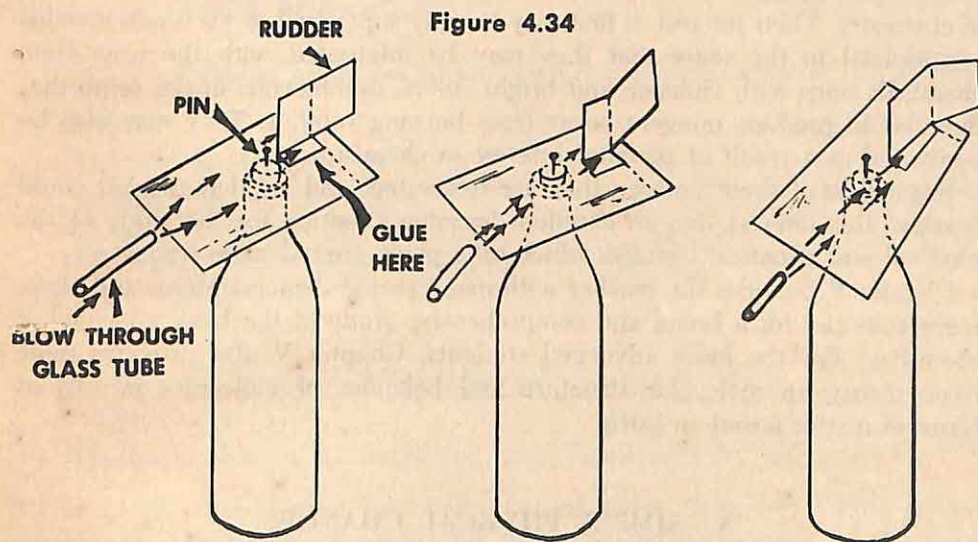
Procedure: Suspend the airplane from the wire bracket by its wing as illustrated in Figure 4.33. Balance the airplane by adding some modeling clay to its nose. Place the electric fan directly in front of the plane and direct the stream of air at its nose. Bend the elevator up. What does the airplane do? Bend the elevator down. What does the airplane do?

Discussion: With the elevator up, the stream of air strikes the elevator forcing the tail down and the nose up. The elevator controls the up and down attitude of the airplane.

11. The Rudder Action of an Airplane (Demonstration 4-6)

Materials: Sheet of cardboard, bottle and cork, straight pin, and electric fan.

Procedure: Construct an airplane rudder assembly as illustrated in Figure 4.34. Bend the rudder first to the right and then to the left as a stream of air from an electric fan is directed at it. In which direction does the rudder assembly turn?



Discussion: With the rudder bent to the right, the plane turns to the right as the air strikes the rudder pushing the tail to the left and the nose to the right. With the rudder bent to the left, the plane turns to the left as the air strikes the rudder pushing the tail to the right and the nose to the left. The rudder helps the pilot turn his plane to the left and to the right.

V



The Physical and Chemical Changes Around Us

The great number of sales registered during the Christmas holidays by toy shops and department stores of chemistry sets for young people denotes a profound interest of elementary school children in the study of chemistry. Their interest at first may be only superficial or even mischievous—superficial in the sense that they may be infatuated with the way some chemicals burn with violence and bright colors, mischievous in the sense that they would produce pungent odors from burning sulphur. They may also be motivated as a result of parental interest in chemistry.

Regardless of their motives, they are motivated, and an alert teacher could “parlay” this interest into an excellent learning situation for the study of the physical and chemical changes which take place around us everyday.

Chapter V provides the teacher with many varied demonstrations and classroom activities for a broad and comprehensive study of the basic concepts of chemistry. For the more advanced students, Chapter V also provides some basic theory on molecular structure and behavior of molecules in various forms of matter found on earth.

A. SIMPLE PHYSICAL CHANGES

1. Change in Shape and Size of Objects (Demonstration K-6)

Materials: Wire, paper, modeling clay, and a wooden stick.

Procedure: Bend a piece of wire, crumple up a sheet of paper, knead a piece of modeling clay, and break a stick into two parts.

Discussion: These are all physical changes, which either change the shape of a material or change its size but not the material itself.

2. Changes Brought About by Using a Material (Activity K-6)

Materials: Stick of chalk, pencil, and sheet of fine sandpaper.

Procedure: Rub a *pointed* piece of chalk back and forth across a chalk board. What happens to the point? Rub a sharply pointed soft pencil (No. 2 or softer) across a sheet of fine sandpaper. What happens to the point?

Discussion: The pointed stick of chalk soon wears away into tiny dust particles which can be observed falling into the chalk tray. The sharp pencil point also wears away and the tiny graphite dust can be collected by tilting the paper on edge over another white sheet of paper.

3. Changing a Substance with Heat (Demonstration K-6)

Materials: Chocolate candy bar, butter, solder, soldering iron, two coffee can lids, and a hot plate.

Procedure: Place two coffee can lids on a hot plate. Put a chocolate candy bar on one and a piece of butter on the other. What happens to the chocolate and the butter? Energize an electric soldering iron and place it near a piece of solder. What happens to the solder?

Discussion: The chocolate and butter begin to melt slowly. This is a physical change in *shape* and in *state*. If they are allowed to cool, they will regain their physical state but not their shape. The solder, too, melts and changes its shape and state. The word *state* refers to the physical condition of an object—as a liquid, solid, or gas.

4. Changes Brought About by Adding Two Substances Together (Demonstration K-6)

Materials: Jar of water and ink.

Procedure: Pour a few drops of ink into a jar of water and stir. What happens?

Discussion: The ink appears to spread throughout the water and the water becomes tinted like the color of the ink.

B. SIMPLE CHEMICAL CHANGES

1. Things that Rust and Things that Don't Rust (Activity K-6)

Materials: Two wooden toothpicks, two pieces of glass, two copper pennies, two steel nails, two steel paper clips, glass jar, and some sand.

Procedure: Fill a glass jar with moist sand and cover the toothpicks, pieces of glass, steel nails, and paper clips with the moist sand. Leave them in the moist sand for about two days or longer. After this time has elapsed, remove each object and inspect it for rust spots.

Discussion: The only materials that will rust will be the two steel paper clips and steel nails, provided they are not coated with some type of rust resistant material or are made of stainless steel.

2. Moisture Causes Rust (Activity K-6)

Materials: Jar of moist sand and six new steel nails without rust spots.

Procedure: Place two steel nails in a jar of moist sand. Set the jar in a safe place in the classroom away from direct sun and heat. Place two new steel nails on the window ledge outside the window of your classroom. Place two new steel nails inside in the warm, dry sunlight or on the radiator in the classroom. After a few days investigate each nail for rust spots. If none of the nails have rust spots, continue the experiment for two more days.

Discussion: The two nails which were in the moist sand and outside the window will have traces of rust on them after several days. The two nails which were in a warm, dry place inside the classroom will not have rust spots on them. Dissolved oxygen in water reacts with iron or steel causing *oxidation*, which produces *rust*. The steel nails will also rust when exposed to the air, but the rate of oxidation is considerably less in dry air than in moist air.

3. Protection Against Rust (Activity K-6)

Materials: Six new nails without rust spots, small can of black enamel paint, oil, and some string.

Procedure: Tie a separate length of string to each of four nails. Dip two nails in a can of black enamel and hang them up to dry. Dip two nails in some oil and hang them up to allow the excess oil to drip off. Place all six nails outside the classroom window. After a few days, inspect each nail for rust spots.

Discussion: The unpainted and unoiled nails will have rust spots on them. Painting and oiling iron and steel objects will protect them from rusting for a long period of time because it is difficult for the air to come in contact with and react with the metal.

4. The Sun Causes Chemical Changes (Activity K-6)

Materials: Colored construction paper and several small toy blocks or any kind of one-dimensional opaque cutout.

Procedure: Place a sheet of colored construction paper in the sunlight and arrange several small toy blocks or opaque cutout on top of the paper in any desired pattern. Allow the paper and blocks to remain in the sunlight without being disturbed. After several days, remove the blocks. What has happened to the paper?

Discussion: The areas of the paper covered by the blocks will retain their color while the areas which were exposed to the direct sunlight will appear lighter. The sunlight will have *bleached* the area of the paper that was *not* covered by the blocks. Blueprint paper and photographic printing paper will show the same discoloring in less time.

5. Chemical Reactions with Household Bleach (Demonstration K-6)

Materials: Jar of household bleach, colored construction paper, colored cloth, and a medicine dropper.

Procedure: Squeeze a few drops of household bleach onto a sheet of colored construction paper and a strip of colored cloth. What happens?

Discussion: The household chemical known as *bleach* contains a substance called chlorine which is a *bleaching* agent. It reacts with the coloring in the paper and in the cloth. The resulting light spots are analogous to the light spots on the paper caused by the sunlight.

6. Magic Writing with Chemicals (Activity K-6)

Materials: Lemon juice, vinegar, white notebook paper, matches, and a candle.

Procedure: Dip a match stick in lemon juice or vinegar and write a few words on a sheet of notebook paper. Have the children write a secret message. After the lemon juice or vinegar dries on the paper, hold the writing a few inches above a candle flame. What do you observe happening?

Discussion: The writing begins to appear on the paper in brown colored letters. Lemon juice and vinegar are both chemically *weak acids*. As heat is applied to the chemically treated paper, a chemical reaction occurs in the lemon juice or vinegar, and the writing appears. In many chemical reactions heat provides the necessary energy for the reaction to get started.

C. THE SIMPLE PHYSICS AND CHEMISTRY OF WATER

1. Water May or May Not Have Color (Demonstration K-6)

Materials: Jar of clean drinking water and some soil.

Procedure: Pour some clear, clean drinking water into a clean jar. Describe its color. Add a handful of soil to the water. Describe its color now.

Discussion: Water from the drinking fountain is clear and colorless. Drinking water should be clear, clean, and colorless. Water, however, is not always round this way. Lakes, streams, ponds, and the ocean water has color. The color comes from the many foreign materials found in it, such as particles of soil. The depth of the water affects the color of the water too. Deep water, for example, absorbs more of the color spectrum and appears bluer and darker. Beware of water with an unusual color.

2. Water May or May Not Have Taste or Odor (Demonstration and Activity K-6)

Materials: Jar of clean drinking water and salt.

Procedure: Clean and sterilize a glass jar and fill it with clean drinking water. Smell the water and describe its smell. Taste the water and describe its taste. Add some salt to the water; smell and taste it again.

Discussion: Water from the drinking fountain is normally tasteless and

odorless unless it has been chemically treated with chlorine. After the salt is added, the water will taste and smell salty. Water is not always odorless and tasteless, especially that which is found in streams, lakes, ponds, and oceans. Much decayed animal and plant matter found in water will give it a taste and an odor. Beware of water with a strange taste or odor. Some of the Boy or Girl Scouts in your classroom may be familiar with water purifying tablets called "Halazone" and could demonstrate the technique of making water safe to drink.

3. Water Feels Wet (Demonstration and Activity K-6)

Materials: Jar of clean drinking water and a bar of soap.

Procedure: Place your fingers in a jar of clean drinking water and describe how it feels. Drop a bar of soap in the jar and then describe how the water feels.

Discussion: Water from the drinking fountain is usually described as feeling wet. When the soap was added, it felt wet and slippery. Water found in some lakes, ponds, and streams may feel wet and slippery too. Decayed matter in the water will often feel slippery or slimy. Beware of slimy water.

4. Water Can Flow Through Tiny Spaces (Demonstration K-6)

Materials: Two large glass jars, wire kitchen strainer, piece of cloth, paper towel, and water.

Procedure: Hold the wire kitchen strainer, cloth, and paper towel up to the light. Can you see through all of them? Fill one jar with water and pour the water through a kitchen strainer, then through a piece of cloth, and then through a paper towel into an empty jar. Does the water flow through all these materials?

Discussion: The spaces between the wires in a kitchen strainer are large enough to allow a great deal of light through, and water too flows through easily. The spaces between the fibers of the cloth allow very little light through. The paper is *translucent*, letting very little light through and giving little or no evidence of space between the fibers. The water passes easily through the kitchen strainer and the cloth, flowing through the spaces between the wire or cloth fibers. The water also passes through the very tiny spaces between the fibers of paper but very slowly. A magnifying glass will reveal these tiny spaces in the paper.

5. Condensation of Water in the Air (Demonstration K-6)

Refer to Chapter IV, Section D, Demonstration No. 3.

6. Evaporation of Water (Activity K-6)

Materials: Metal lid from a jar, ink, and water.

Procedure: Pour some water into a metal lid from a jar. Add a few drops of ink to the water to color it. Place the lid with water in a safe place in the

room and allow it to stand for two days. What happens to the water?

Discussion: The water disappears due to evaporation, but the ink remains behind as a dry stain in the jar lid. Where did the water go? The next activity will help explain this.

7. Evaporation and Condensation (Activity K-6)

Materials: Metal lid from a jar, ink, gallon mayonnaise jar, and water.

Procedure: Fill the jar lid with water and add a few drops of ink for coloring. Place the gallon mayonnaise jar upside down over the lid containing colored water. Allow this apparatus to set in a safe place, not in the direct sunlight or in any hot place, until all the water has evaporated. What do you observe inside the large mayonnaise jar?

Discussion: The colored water will evaporate, leaving behind the dry ink stains in the jar. As the water evaporates the water vapor escapes into the air in the large mayonnaise jar. The water vapor strikes the cool sides of the jar and *condenses*. As condensation continues, large droplets of water form on the inside of the jar and drip down the sides. The answer to the question, "Where does the evaporated water go?" is plainly seen. It escapes into the air around us, as it escaped into the air in the jar.

8. How Much Water Is There in Plants? (Activity K-6)

Materials: Ripe tomato, stalk of celery, carrot, two small baby food jars, wooden potato masher, a tin can, and a tea leaf strainer.

Procedure: Place a tomato in a tin can and squash it with a wooden potato masher. Pour off the liquid from the can, filtering it through a paper towel into a baby food jar. Scrape the remains of the tomato out of the can, making sure you get it all, and put it in another baby food jar. Compare the amount of tomato pulp with the amount of water.

Discussion: The amount of water in a tomato is 50 per cent or more, depending on the tomato itself and how well you squeeze it. The same thing can be done with shredded carrots and cut up celery stalks. The children will be surprised at the amount of water found in a seemingly solid carrot or stalk of celery. Have them keep a record of the amount of water in each plant with which they work.

9. How Much Water Is There in Plants? (Activity K-6)

Materials: Potato, apple, sheet of notebook paper, and a pencil.

Procedure: Cut a slice of potato and a slice of apple about $\frac{1}{4}$ inch thick. Lay them flat on a sheet of notebook paper and make an outline tracing of each slice on the paper. Label each outline drawing. Remove the slices and place them in the sunlight to dry. After a few days, place the slices of potato and apple over their respective outlines on the paper. What has happened?

Discussion: The water in the slices of potato and apple has evaporated, causing them to shrink. They no longer fill the original outline of themselves on the paper.

10. Quantitative Study of the Amount of Water in Plants (Activity 4-6)

Materials: Potato, apple, carrot, celery, and a balance scale.

Procedure: Using a balance scale, find the weight of a slice of potato, a slice of apple, a stalk of celery, and a carrot. Record their weights. Place them in direct sunlight until they have become dry and hard. Weigh them once again and compare their *dry* weight with their *wet* weight.

Discussion: The weight of the dry plants will be considerably less than when they were fresh. The water in the cells of the plants has evaporated in the warm sunlight, reducing their size and weight.

11. Water Expands When It Freezes (Activity K-6)

Materials: Glass jar with screw-on lid, plastic bag, and water.

Procedure: Fill a jar with water and screw the lid on tightly. Place the jar of water in a plastic bag and set it in a freezer (cafeteria ice cream freezer box will do well) overnight. Carefully remove the plastic bag containing the jar of water from the freezer the next day. What has happened to the water and the glass jar?

Discussion: The water has frozen into ice. As the water froze and expanded, it broke the jar. When water freezes, the *molecules* arrange themselves in such a way that the crystals they form are about $\frac{1}{9}$ larger in volume than the volume of water from which they originated. This explains the breaking of the jar. The water could not expand through the mouth of the jar with the lid on it, so it expanded in another direction. This activity can also be done with a cardboard milk container, which will bulge instead of breaking. Also try a milk bottle with a paper disk lid on it.

12. Materials that Dissolve in Water and Materials that Do Not Dissolve in Water (Activity K-6)

Materials: Copper penny, glass marble, piece of wood, paper, soap, rock candy, lump of sugar, cotton cloth, paper clip, piece of plastic, salt, rubber, and 12 glass jars.

Procedure: Fill a dozen jars with water and place each of the 12 materials mentioned above in a separate jar. Label each jar with the name of the material in it. Each day investigate each jar to see which materials have dissolved or are dissolving, which substances dissolve completely, which materials do not dissolve at all.

Discussion: The soap, rock candy, lump of sugar, and salt dissolved completely. The lump of sugar dissolved faster than the rock candy and soap. The paper became very soft, whereas the wood, copper penny, plastic, rubber, paper clip, and marble did not dissolve at all.

13. Making Materials Dissolve Faster by Stirring (Activity K-6)

Materials: Two lumps of sugar, salt, four jars filled with water, and a stirring rod.

Procedure: Drop a lump of sugar in each of two jars of water. Stir one with a stirring rod and not the other. Which one dissolves faster? Drop a teaspoonful of salt in each of two jars of water. Stir one with a stirring rod but not the other. Which dissolves faster?

Discussion: The lump of sugar and the teaspoon of salt in the jars which were stirred will dissolve faster than those in the other two jars of water which were not stirred. Stirring exposes more surface area of the sugar more quickly.

14. Making Materials Dissolve Faster by Heating (Demonstration K-6)

Materials: Two pieces of rock candy of equal size, two pieces of soap of equal size, two glass jars, two glass pyrex beakers, water, and a hot plate.

Procedure: Fill the two glass jars with water and place a piece of rock candy in one of them and a piece of soap in the other. At the same time, drop a piece of rock candy into a pyrex beaker of boiling water and a piece of soap into another pyrex beaker of boiling water. Which piece of rock candy and which piece of soap dissolve first?

Discussion: The pieces of rock candy and soap which were dropped into boiling water dissolved very fast, compared with the others which were put in cool water. Heat helps water to dissolve substances faster because it provides the energy necessary for producing a change in state.

15. Adding Substances to Boiling Water (Demonstration 4-6)

Materials: Granulated sugar, table salt, two pyrex beakers, water, and a hot plate.

Procedure: Boil two beakers of water on a hot plate. Add several teaspoonfuls of salt to the boiling water of one jar and observe what happens. Add several teaspoonfuls of sugar to the boiling water of the other jar and observe what happens.

Discussion: Each time salt or sugar is added to the boiling water, the boiling stops for a few seconds. This is made evident by the apparent decrease in the number of bubbles. When another substance (such as salt and sugar) is added to water, the water is no longer just plain water. It is a new substance—salt-and-water or sugar-and-water. It takes more heat to boil salt water than it does fresh water. The momentary decrease in the boiling shows this. The water with the salt had to absorb more heat before it started to boil again. The same is true with the sugar-and-water. The boiling temperature of water is raised when another substance, other than a volatile substance, is added to it.

16. Adding Other Substances to Water Lowers the Freezing Temperature of Water (Activity 4-6)

Materials: Three small baby food jars, three plastic bags, sugar, salt, and water.

Procedure: Fill three jars of equal size with water and add a teaspoonful

of salt to one jar and a teaspoonful of sugar to another. Dissolve the sugar and salt in the water by stirring. Label each jar. Do not add any foreign substance to the third jar. Place all three jars in a freezer or outside the classroom window on a day when the temperature is below freezing. Observe them carefully once every ten minutes. Record the time it takes for each jar of water to freeze. Which one freezes first? second? third?

Discussion: The water without any sugar or salt dissolved in it will freeze first. The water with dissolved sugar will freeze next and the salt water last. We now find that when substances are dissolved in water, they will lower the freezing temperatures of water. For this reason, *rock salt* is used to melt snow and ice on roads and sidewalks. This also explains why bodies of salt water rarely freeze over in winter when fresh water in the same locality may have several inches of ice.

17. Things which Absorb Water and Things which Don't Absorb Water (Activity K-6)

Materials: Cotton cloth, paper towel, blotter paper, strip of leather, strip of metal, strip of plastic of equal width and length, a watch, pie tin and water.

Procedure: Arrange the ends of the various strips of material of equal length in a pie tin filled with water as illustrated in Figure 5.1. What happens?

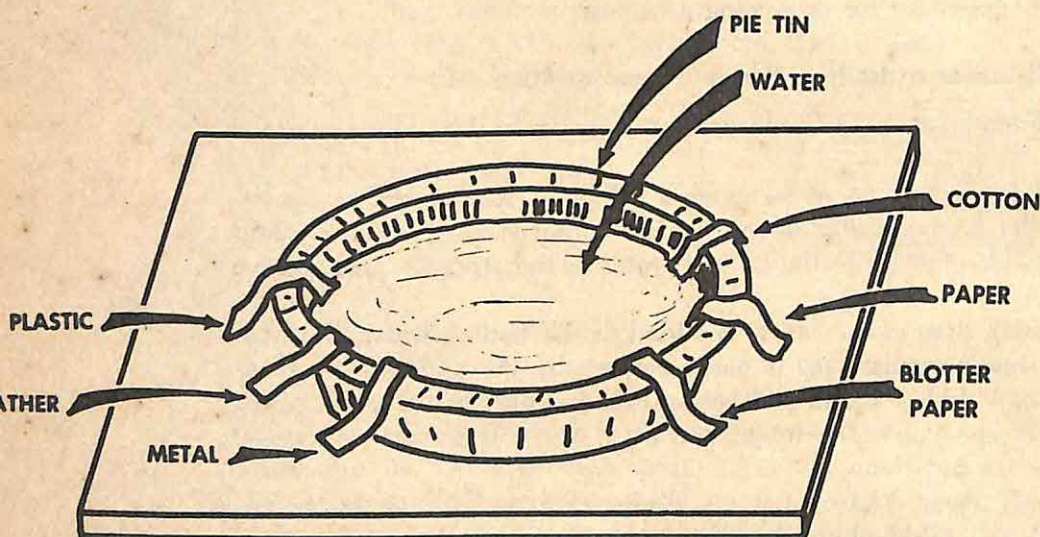


Figure 5.1

A watch may be used to measure the time it takes for the water to climb up and over the edge of the pie tin in each individual material until they are entirely wet.

Discussion: The cotton cloth, paper towel, blotter paper, and leather strip will absorb water and the water will appear to climb up into these materials. Some will absorb the water faster than others. The strips of waxed paper, metal, and plastic will not absorb the water at all. We find, then, that materials that have tiny spaces between their fibers will absorb water, and materials that do not have such tiny spaces will not absorb water.

18. Materials which Hold Water and Materials which Don't Hold Water (Activity K-6)

Materials: Glass jar, plastic bag, tin can, stocking, paper bag, wire kitchen strainer, and some water.

Procedure: Pour water into the glass jar, plastic bag, tin cup, stocking, paper bag, and wire kitchen strainer. Which materials hold water and which do not? Why?

Discussion: The glass jar, the plastic bag, and the tin can held water. The stocking, the paper bag, and the wire strainer did not hold water.

The spaces between the fibers of cloth in the stocking and between the fibers of the paper in the paper bag allowed the water to escape. The paper bag will, however, hold water for a short period of time. The space between the strands of wire of the kitchen strainer allowed the water to escape. The glass, plastic, and metal do not have spaces through which the water can flow.

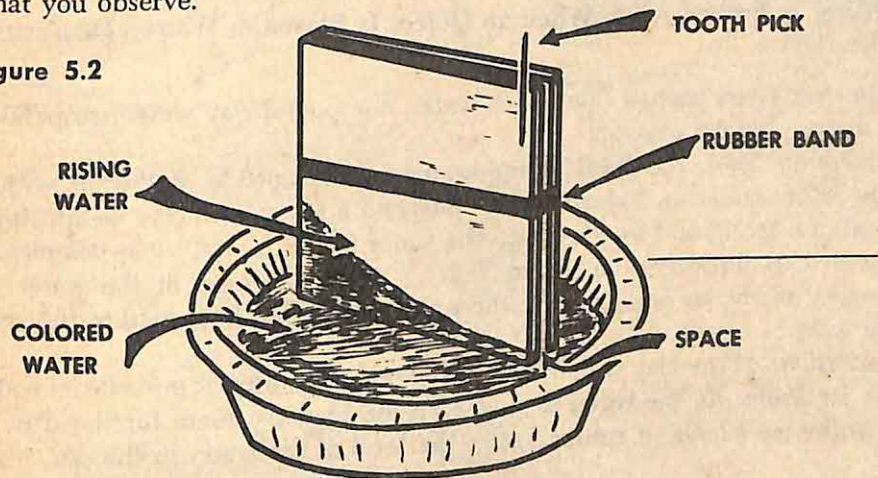
A magnifying glass can be used to investigate the spaces between the fibers of cloth and paper.

19. Absorption by Capillary Action (Activity 3-6)

Materials: Two panes of glass 4 by 4 inches, pie tin, rubber band, toothpick, tape, and water.

Procedure: Arrange the materials as illustrated in Figure 5.2. Color the water in the pie tin with ink. Observe the apparatus frequently and record what you observe.

Figure 5.2



Discussion: The colored water will climb up between the two panes of glass. It will climb higher on the side away from the toothpick where the space between the panes of glass is smaller. As the thin layer of water between the two panes of glass evaporates, a low pressure area is created immediately above this layer. The higher air pressure (atmospheric), which is pressing down on the surface of the water in the pan, forces the water up between the two panes of glass.

20. Things that Float and Things that Don't (Demonstration K-6)

Materials: A stone, piece of metal, modeling clay, pane of glass, cork, wood, paper, sheet of plastic, and a glass aquarium filled with water.

Procedure: Place each material listed above in the aquarium of water one at a time. Make a list of those that sink and a list of those that float.

Discussion: The stone, the piece of metal, the ball of modeling clay, and the pane of glass sink to the bottom of the aquarium. The cork, wood, paper, and plastic sheet float on the surface of the water. The latter materials are light in weight in comparison with the other materials of comparable size.

21. Changing the Shape of an Object Will Make It Float (Demonstration 3-6)

Materials: Modeling clay and an aquarium filled with water.

Procedure: Drop a solid ball of modeling clay in the aquarium of water. What happens to it? Remove the ball of clay from the water and shape it into a hollow bowl or into the shape of a hollow canoe. Place it gently on the water. What happens to it?

Discussion: The ball of clay sinks to the bottom of the aquarium. The bowl or canoe shaped from the ball of clay floats on the surface of the water. The change in the shape of the ball of clay makes it larger in total surface area, allowing it to float. This is illustrated in Figure 5.3. Heavy objects can be made to float without changing their weight if they are merely made larger. The volume of the object has changed but not its weight.

22. Water Is Pushed Aside When an Object Is Placed in Water (Demonstration 3-6)

Materials: Glass jar half filled with water, one pound clay weight suspended from a string, and a crayon.

Procedure: Mark the level of the water on the outside of the jar with a crayon as illustrated in Figure 5.4(a). Suspend a one pound clay weight from the end of a string and lower it into the water in the jar until it is completely submerged as illustrated in Figure 5.4(b). Mark the level of the water on the outside of the jar and compare the two marks. What happened to the level of the water?

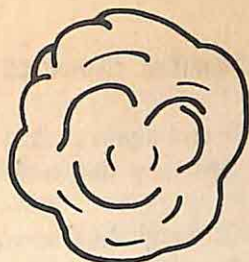
Discussion: As the clay weight is lowered into the water, it pushed the water in the jar aside. As the water is pushed aside to make room for the clay, it rises in the jar which, of course, raises the level of the water in the jar.

23. The Force of Buoyancy and the Weight Loss of a Submerged Object (Activity 4-6)

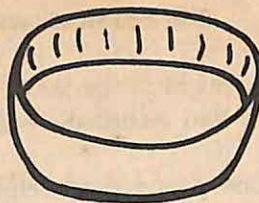
Materials: Glass jar half filled with water, one pound clay weight suspended from a string, and spring scale calibrated in ounces and pounds.

Procedure: Suspend the one pound clay weight from the spring scale, using a string as illustrated in Figure 5.5. Record its weight in ounces. Submerge

Figure 5.3



SOLID CLAY BALL

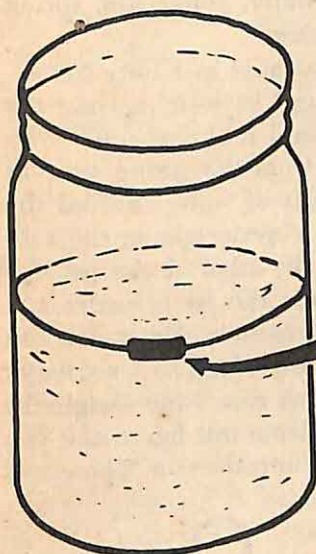


HOLLOW CLAY BALL



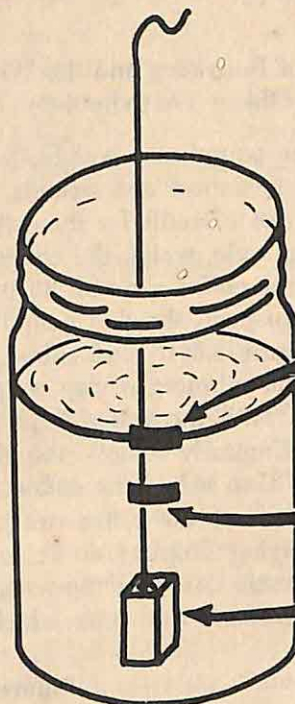
HOLLOW CLAY CANOE

Figure 5.4



(a)

CRAYON
MARK



(b)

2nd MARK

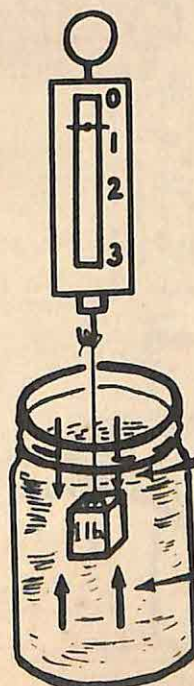
1st MARK

CLAY
WEIGHT

Figure 5.5



(a)



(b)

FORCE OF
GRAVITY

FORCE OF
BUOYANCY

the same one pound weight in the jar of water and again record its weight in ounces. Compare the two recorded weights. Are they the same? If not, why not?

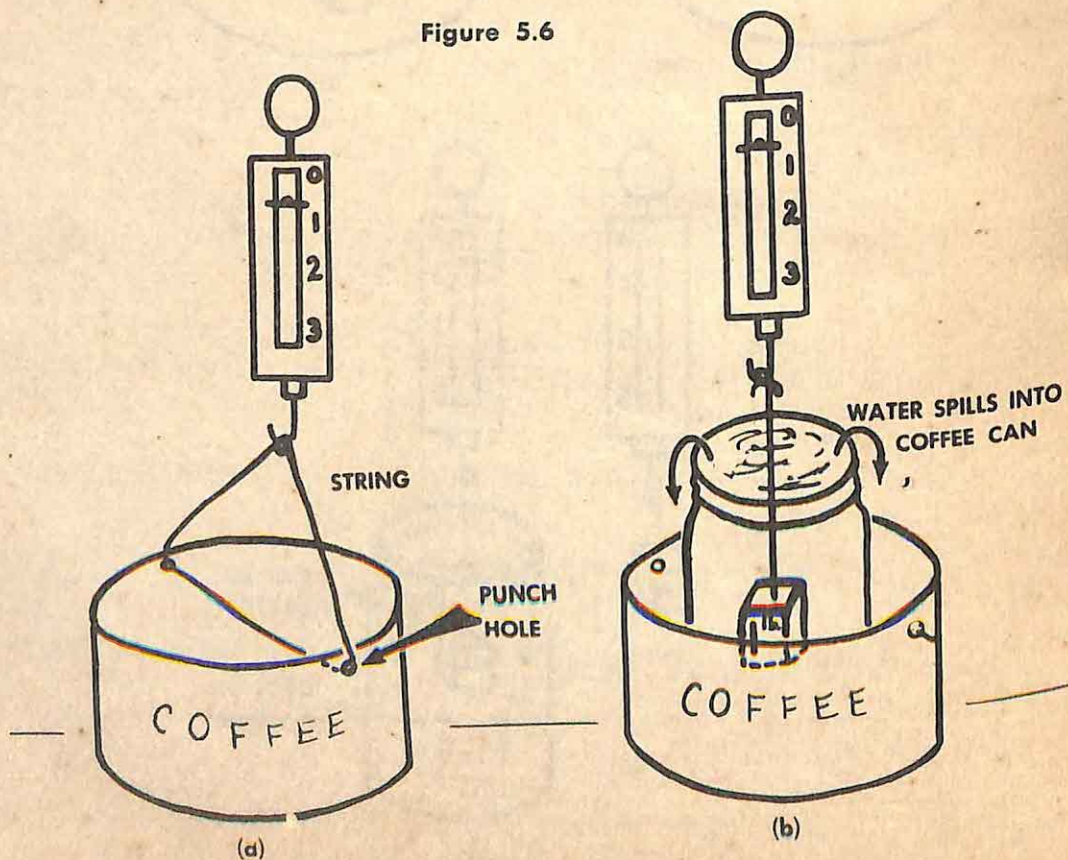
Discussion: The one pound clay weight will weigh less in water than out of water. The difference in weight is caused by the *force of buoyancy* acting in an opposite direction to that of the *force of gravity* as illustrated in Figure 5.5(b).

24. The Force of Buoyancy and the Weight of the Water Pushed Aside by a Submerged Object (Activity 4-6)

Materials: One pound clay weight, jar filled with water, coffee can, spring scale calibrated in ounces and pounds, and some string.

Procedure: Make a handle for the coffee can as illustrated in Figure 5.6(a). Using the spring scale, weigh the coffee can and record its weight. Place the glass jar inside the coffee can and fill it with water until it almost spills over. Using a string, suspend the one pound clay weight from the spring scale as illustrated in Figure 5.6(b) and submerge it in the jar of water. Record the weight loss of the submerged clay weight. Hold the clay weight in the submerged position until the water stops spilling over the edge of the jar into the coffee can. Carefully remove the clay weight from the jar of water and then lift the jar from inside the coffee can. Allow as much water as you can to drip off the jar into the coffee can before setting it aside. Use your finger to push the clinging droplets of water into the coffee can. Now weigh the coffee can and water. Subtract the weight of the can from this figure and you will have the weight of the water which spilled over into the can. There will

Figure 5.6



be a slight error due to the fact that some of the water which clung to the sides and bottom of the jar could not be removed. Compare the *weight of the water* with the *weight loss* of the submerged clay weight. How do they compare?

Discussion: The two weights are almost the same. The weight of the water pushed aside by the submerged clay weight will be slightly less than the weight loss of the submerged clay weight. This is due to the error in collecting the water which spilled over the side of the jar.

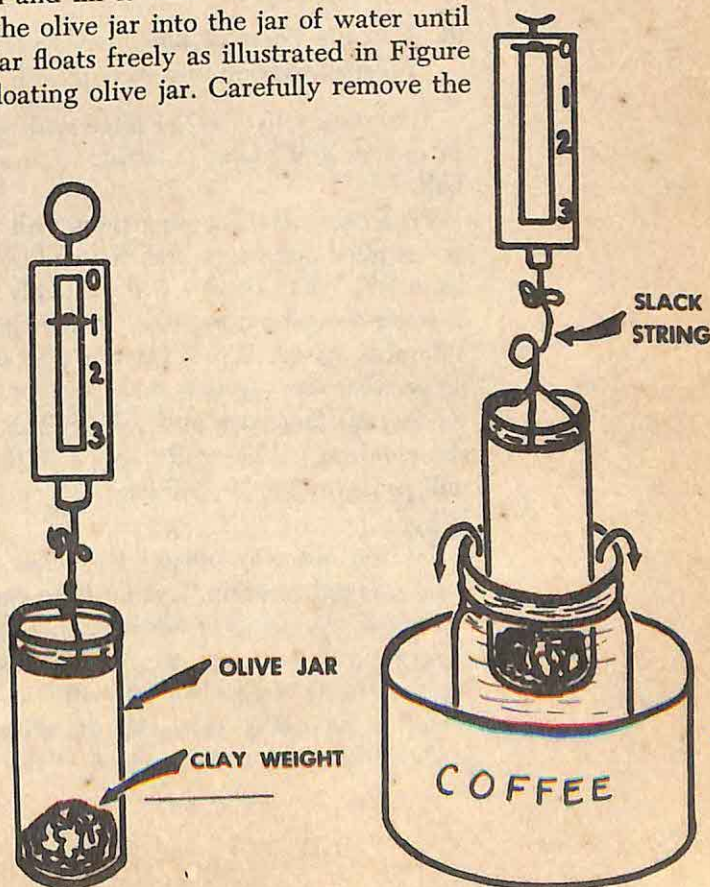
We can say, then, that the force of buoyancy can be found in two ways. *First*, by measuring the weight loss of the object submerged in water and, *secondly*, by measuring the weight of the water pushed aside by the submerged object.

25. The Force of Buoyancy and the Loss of Weight of a Floating Object (Activity 4-6)

Materials: Olive jar, jar filled with water, coffee can, spring scale (calibrated in ounces and pounds), and string.

Procedure: Place a clay weight at the bottom of a covered olive jar so that the olive jar will float upright in a jar of water. Using a string, suspend the olive jar with weight from a spring scale as illustrated in Figure 5.7(a) and record its weight. Make a handle for the coffee can as illustrated in Figure 5.6(a). Weigh the coffee can, using the spring scale, and record its weight. Place the glass jar inside the coffee can and fill it with water until it almost spills over. Carefully and slowly lower the olive jar into the jar of water until the string becomes *slack* and the olive jar floats freely as illustrated in Figure 5.7(b). Record the weight loss of the floating olive jar. Carefully remove the

Figure 5.7



olive jar from the jar of water and then lift the jar from inside the coffee can. Allow as much water as possible to drip off the jar into the coffee can before setting it aside. Use your finger to push the clinging droplets of water into the coffee can. Now weigh the coffee can and water. Subtract the weight of the coffee can from this figure, and you will have the weight of the water that spilled over into the coffee can. There will be a slight error due to the fact that some of the water which clung to the sides and bottom of the jar could not be removed. Compare the *weight of the water* with the *weight loss* of the floating olive jar. How do they compare?

Discussion: The two weights are almost the same. The weight of the water pushed aside by the floating olive jar will be slightly less than the weight loss of the olive jar. This, again, is due to the error in collecting the water which spilled over the side of the jar.

It is important to note in this activity that the weight loss of the floating olive jar was 100 per cent. The force of buoyancy supporting the olive jar was as great as the force of gravity which was acting in the opposite direction to give it weight and cause it to sink. The weight of the water pushed aside by the floating olive jar is a measure of the force of buoyancy, too. We can say, then, that an object will float when it can push aside enough water to equal its own weight. Now one can see why the clay ball floated when we changed its shape into a bowl or canoe in Activity 21 of this section.

A ship made of steel will float if it is big enough to push aside enough water to equal its own weight.

26. Can the Force of Buoyancy Ever Be Greater Than the Force of Gravity? (Demonstration and Activity 4-6)

Materials: Olive jar, jar filled with water, coffee can, spring scale (calibrated in ounces and pounds), string, aquarium filled with water, and a ping pong ball.

Procedure: Hold a ping pong ball in your fingertips and submerge it in a water filled aquarium. Ask the children, "What will happen to the ball if I release it?" Their answer will probably be, "It will float or pop to the surface." Release the ping pong ball. It does pop to the surface of the water with considerable speed. Why? Place a clay weight at the bottom of a covered olive jar so that the jar will float upright in the water-filled aquarium. Hold the jar in your fingertips and submerge it in the water-filled aquarium. Again ask the children, "What will happen to the olive jar if I release it?" Their answer will probably be, "It will float or pop to the surface as the ping pong ball did." Why?

To find out why objects that float pop to the surface when released from a submerged position, try the following experiment.

Follow the exact procedure described in Activity 25 of this section to determine the amount of water pushed aside by the olive jar and the weight lost by the floating olive jar with the following exception. Do not weigh the water in the coffee can after the olive jar is in the floating position. Instead, push the jar below the surface of the water until the cover is just below the

surface of the water as illustrated in Figure 5.8. Now measure the weight of the water that spilled over into the coffee can (using the same procedure as in Activity 25 of this section). Compare the weight of the olive jar with the weight of the water. How do they compare?

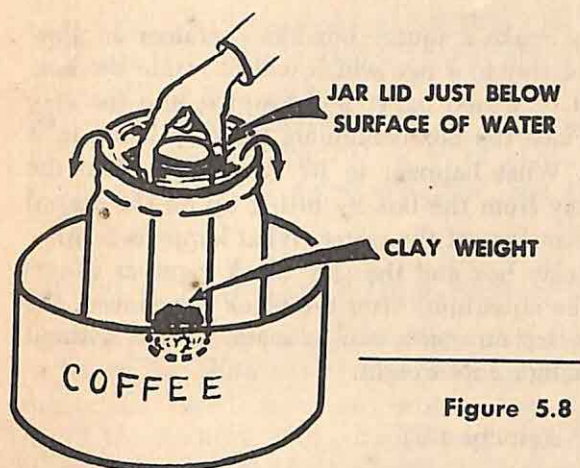


Figure 5.8

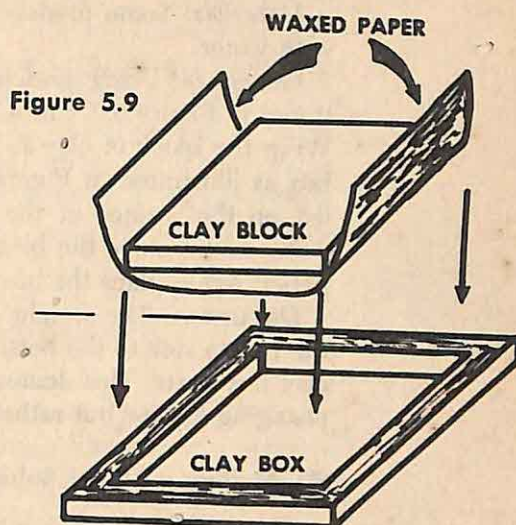


Figure 5.9

Discussion: The weight of the water which spilled over into the coffee can will be greater than the weight of the olive jar. Why? As the jar was forced below the surface of the water, it pushed more water aside than it did when it was in the floating position. The weight of the water collected is equal to (except for the error in collecting the water) the force of buoyancy which caused the olive jar to pop to the surface of the water. In this case the weight of the water will be greater than the weight of the olive jar. The force of buoyancy will be greater than the force of gravity when an object of less density than water is forced to occupy a position in which it displaces more than its own weight.

27. The Shape of a Ship's Hull and the Force of Buoyancy (Activity 4-6)

Materials: Aquarium half filled with water and two one-pound balls of modeling clay.

Procedure: Shape one ball of clay into a broad flat-bottomed boat and the other into a narrow "V" shaped hull of a ship. Float them side by side in the aquarium. Which one floats deeper in the water? Why?

Discussion: The narrow "V" shaped hull will float deeper in the water than the wide flat-bottomed boat despite the fact that they are of equal weight.

The *force of buoyancy* has more surface area to *push* against on the flat bottomed boat than on the "V" shaped hull. Flat bottomed boats are generally used in shallow, calm water. The "V" shaped deep draught vessels are generally used in deep bodies of water. Their deep draughts give them calmer sailing on rough seas. They tend to cut through the wave rather than bob up and down.

28. Making an Object Float by Changing Its Weight but Not Its Size (Demonstration 4-6)

Materials: Some modeling clay, waxed paper, and an aquarium half filled with water.

Procedure: Using modeling clay, make a square box-like container as illustrated in Figure 5.9. Cut a block of clay to a size which will fit inside the box. Wrap the block of clay in a sheet of waxed paper and insert it into the clay box as illustrated in Figure 5.9. Place the box containing the clay block in it flat on the surface of the water. What happens to it? Remove it from the water and remove the block of clay from the box by lifting up on the waxed paper. Again place the box on the surface of the water. What happens to it?

Discussion: The weight of the clay box and the clay block together causes the box to sink to the bottom of the aquarium. After the block is removed, the clay box floats. This demonstrates that an object can be made to float without changing its size but rather by changing its weight.

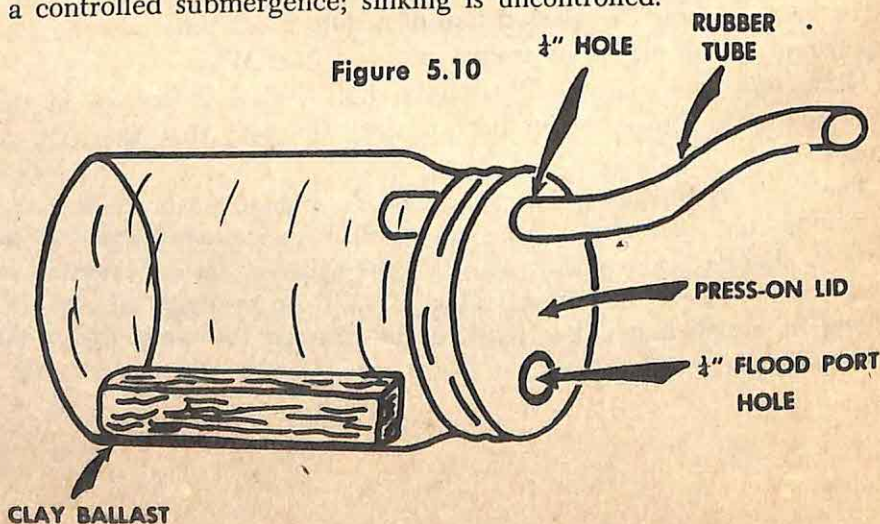
29. Making a Model Submarine (Activity 4-6)

Materials: Quart jar with a press-on lid, modeling clay, three-foot length of rubber or plastic tubing, and an aquarium filled with water.

Procedure: Construct a model submarine as illustrated in Figure 5.10. The press-on lid will make it easier to get the end of the rubber tubing at the top part of the submarine. The clay ballast will allow the submarine to lie in the horizontal position when it is blown dry of water and is floating on the surface. Modeling clay can also be used to patch leaks around the hose and jar lid or around the lid and jar itself.

To operate the submarine, allow the air inside the jar to escape through the rubber tubing as the water rushes into the flood port at the bottom. The submarine will slowly sink to the bottom. To surface the submarine, again blow air into the rubber tubing to force the water out through the flood port. As the water is replaced by the lighter air, the submarine becomes lighter and begins to rise to the surface and will float.

With due respect to the men of the United States Submarine Force, the term *dive* is used when the ship submerges and not the word *sink*. Diving is considered a controlled submergence; sinking is uncontrolled.



30. Piling Up Water (Demonstration and Activity 3-6)

Materials: Glass tumbler, medicine dropper, and water.

Procedure: Fill a glass tumbler with water until the water is slightly above the rim of the glass. Fill the medicine dropper with water and squeeze out into the tumbler as many drops as possible until the water actually spills over the rim. How high can you pile the water above the rim of the glass? Why?

Discussion: The surface of the water is like a thin, transparent skin which holds the water together. It is actually the strong attraction of the water (H_2O) molecules to each other which causes this phenomenon. As the weight of the piled-up water gets too great, the molecules separate and the water flows.

31. Surface Tension and a Drop of Water (Demonstration 3-6)

Materials: Waxed paper, medicine dropper, and water.

Procedure: With a medicine dropper, squeeze a few drops of water onto a sheet of waxed paper, one drop on top of the other. What do you observe about the resulting large drop of water? Add a few more drops of water to the one on the waxed paper. What happens?

Discussion: The drop of water on the waxed paper gets larger as more drops are added. As each drop is added, it appears as if it is entering a transparent plastic bag which gets larger with each drop of water. *Surface tension* holds the drop together until the weight of the water becomes so great that it separates the water molecules and is allowed to flow, forming either other smaller drops or a long, odd-shaped column of water.

32. Surface Tension Helps Objects to Float (Activity 3-6)

Materials: Glass jar, two razor blades, two needles, paper clip, and water.

Procedure: Fill a jar with water and attempt to float a double edged razor blade and a needle on its surface. Figure 5.11 illustrates how this can be accomplished. Place the razor blade or needle on the wire bracket made from a paper clip and carefully lower it into the water. As the object floats, remove the bracket as shown by the arrows in Figure 5.11.



Figure 5.11

Discussion: The razor blade and needle normally would not float because they cannot displace their own weight. This can be demonstrated by dropping them into the water. However, in this case the *surface tension* of the water will support the weight of the needle and razor blade if the latter are carefully placed in the water.

33. Surface Tension and Air Pressure Prevent Water From Flowing Through a Cotton Cloth (Demonstration 3-6)

Materials: Glass jar, cotton cloth, rubber band, and water.

Procedure: Fill a glass jar with water and cover the mouth of the jar with a wet cotton cloth, using a rubber band to hold it in place. Invert the jar so that its mouth is facing down. What happens to the water in the jar? Why?

Discussion: The water in the jar will not flow through the cloth. The *surface tension* of the water between the fibers of cotton tends to seal the holes. The *atmospheric pressure*, which exerts a greater force upward than the column of water in the jar does downward, acts on the wet cotton cloth as it would on a card if it were used to cover the mouth of the jar. (Refer to Demonstration 2, Section B, Chapter IV.) Two factors, then, prevent the water from flowing out of the jar—*surface tension* and *atmospheric pressure*.

34. There Are Limits to the Strength of Surface Tension (Demonstration 3-6)

Materials: Three metal jar lids, aquarium filled with water, hammer, wooden board, and various sizes of nails.

Procedure: Place the metal lids face down on a wooden board and puncture holes in them, using a nail and a hammer. Puncture the first lid with a fine nail, the second with a coarse nail, and the third with a very coarse nail. Attempt to float each lid (top downward) on the surface of the water in the aquarium. What happens?

Discussion: The lid with the fine holes will float on the surface of the water despite the many holes. This is due to the *surface tension* of the water. The molecules of water are strongly attracted to each other and tend to cover up the holes in the lid like a sheet of plastic. As the holes get larger in successive lids, the surface tension will not be strong enough to support the weight of the lid. The water will leak into the lid, increase its weight, and cause it to sink.

35. Water Is Attracted to Other Substances (Demonstration 3-6)

Materials: Shallow pan of water, glass jar, and a metal jar lid.

Procedure: Place the bottom of a glass jar in the shallow pan of water so that it is about $\frac{1}{4}$ inch below the surface of the water. Raise the jar slowly, making sure that the bottom of the jar is parallel with the surface of the water. Observe the water around the bottom of the jar very closely as it is lifted out of the water. Carry out the same procedure with the metal jar lid. What do you observe?

Discussion: The water will tend to pull up with the glass jar and the metal lid. The water "sticks" to the glass jar and the metal lid. The *molecules* of

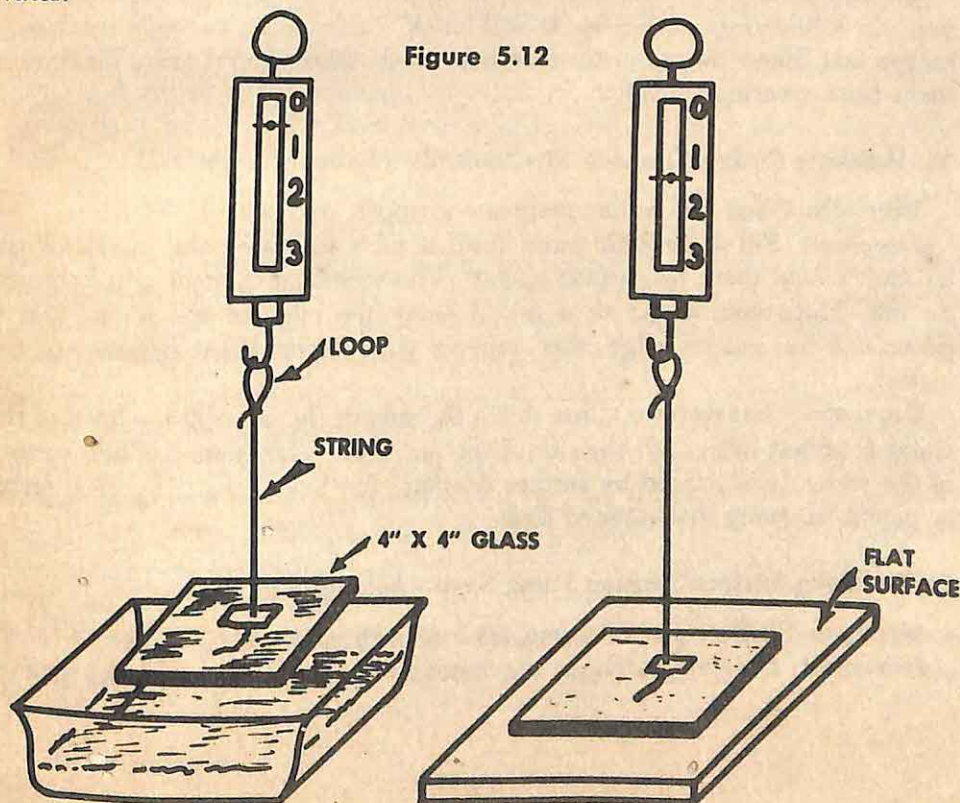
water are attracted to the glass and metal. For this same reason, droplets of water "stick" to the vertical sides of a drinking glass, a tin can, or a plastic carton. When substances which are made up of different *molecules* are attracted to each other, we call this *adhesion*. When substances that are made up of the same *molecules* are attracted to each other, we call this *cohesion*. Water molecules *cohere* to each other.

36. Measuring the Strength of the Surface Tension of Water (Activity 4-6)

Materials: Small square pane of window glass 4 inches square, shallow pan of water, a large flat surface of glass, metal or wooden table top, adhesive tape, spring scale (calibrated in ounces and pounds), and string.

Procedure: Find the center of the 4 by 4 inch pane of glass and tape one end of a length of string to it. Tie a loop in the other end of the string and loop it over the hook of the spring scale as illustrated in Figure 5.12. Weigh the glass and record its weight. Place the glass flat on the surface of the water in the shallow pan. Do not allow it to sink. Pull up on the string by holding the spring scale so that the force exerted on the glass pane will register on the scale. Record this force. Repeat the above procedure with the following exceptions: Pour some water over the surface of the large pane of glass, metal surface, or table top and rest the 4 by 4 inch glass pane in the water. Pull up on the string as before and record the force indicated on the spring scale. How much force was needed to lift the pane of glass from the surface of the water in each case?

Discussion: The force needed to separate the small pane of glass from the thin film of water on the larger pane of glass, or table top, was greater than the force needed to separate the same pane of glass from the surface of the water.



The thin film of water between the two panes of glass, or between the pane of glass and the table top, was strongly attracted to the glass and the table top. The water molecules were trying to hold the glass to the table and the table to the glass, which made the job of pulling them apart more difficult. The depth of the water in the shallow pan weakened the capacity of the *surface tension* to hold the pane of glass because of the water's greater flexibility. The thin layer of water between the small pane of glass and the flat surface on which it was placed had, relatively speaking, little flexibility.

37. Measuring the Strength of the Surface Tension of Oil (Activity 4-6)

Materials: Small square pane of window glass 4 inches square, a large flat surface of glass, metal or a wooden table top, adhesive tape, spring scale (calibrated in ounces and pounds), string, and some oil.

Procedure: Arrange the equipment in the manner illustrated in Figure 5.12. Weigh the glass and record its weight. Pour some oil on the flat surface of the large sheet of glass or table top and spread it evenly over an area large enough to accommodate the area of the 4 inch square pane of glass. Place the pane of glass flat in the oil. Pull up on the string attached to the pane of glass by lifting the spring scale. Observe the indicator on the spring scale and record the force necessary to separate the 4 by 4 inch pane of glass from the flat surface. Compare this amount of force with the amount of force needed to separate the pane of glass from the flat surface when water was used. (Refer to Activity No. 36 for these results.)

Discussion: Oil has a stronger *surface tension* than water. The force needed to separate the pane of glass from the flat surface using oil will be almost twice as great as that required when using water.

Because oil has a greater ability than water to stick to other materials, it is used for lubricating machinery. It will "stick" (adhere to) to metal machinery longer and allow the parts to slide over each other more easily, preventing them from wearing quickly.

38. Breaking Surface Tension Mechanically (Demonstration 3-6)

Materials: Glass jar, water, medicine dropper, and pencil.

Procedure: Fill a jar with water until it piles up above the mouth of the jar and is held there by surface tension. The medicine dropper will help you do this. Place your finger or a pencil along the edge of the jar so that it penetrates the water's edge; then remove your finger. What happens to the water?

Discussion: The water will run down the side of the jar until the level of the water is almost even with the rim of the jar. The transparent skin-like surface of the water (maintained by surface tension) has been broken by your finger or pencil, allowing the water to flow.

39. Breaking Surface Tension Using Soap (Activity 3-6)

Materials: Shallow pan of water, stick of soap, and six toothpicks.

Procedure: Carefully arrange the toothpicks in the center of the pan of

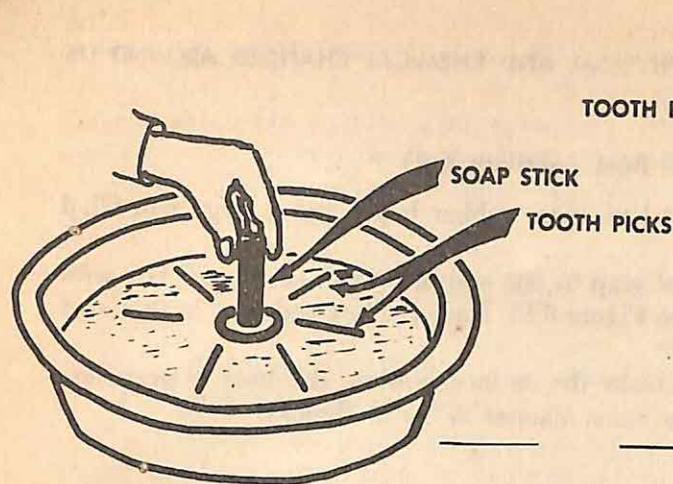


Figure 5.13

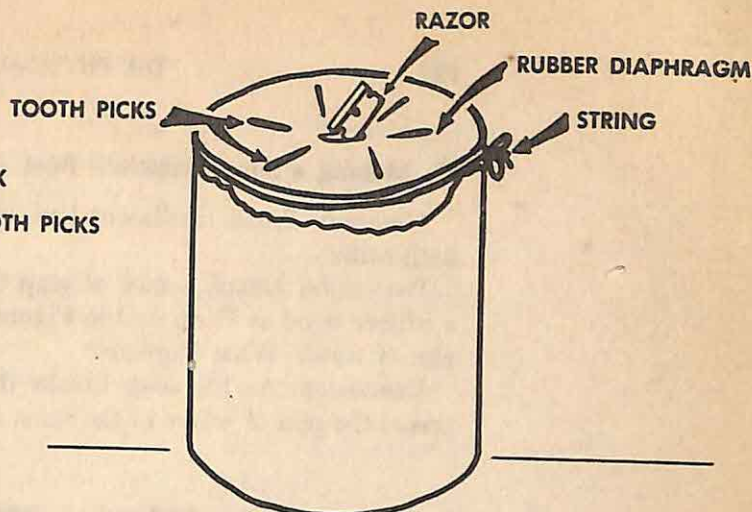


Figure 5.14

water as illustrated in Figure 5.13 so that they radiate from a common center like spokes of a wagon wheel. Grasp the stick of soap in one hand and slowly submerge it in the water at the point from which the toothpicks radiate. What happens to the toothpicks? Using the same water, try to set up the toothpicks as before. What happens?

Discussion: As the soap is placed in the water, the toothpicks move away from the center of the pan of water to the sides of the pan. To repeat the experiment the water in the pan must be changed and the pan thoroughly cleaned and freed from soap. Why the toothpicks move away from the soap has not yet been explained; however, the next demonstration will help you understand what has happened to the surface of the water.

40. Why Surface Tension Is Broken by Soap (Demonstration 4-6)

Materials: Wide mouth gallon can, large rubber balloon, toothpicks, a razor blade, and rubber band or string.

Procedure: Stretch the rubber from a large rubber balloon across the mouth of the jar, holding it in place with a rubber band or string as illustrated in Figure 5.14. This rubber diaphragm will represent the surface of the water, which can be compared to a thin elastic skin. Arrange the toothpicks in the center of the rubber diaphragm as they were arranged on the surface of the water in Demonstration 39 above. Using the razor blade slowly cut a slit in the rubber diaphragm at the center of the radiating toothpicks. Observe what happens to the rubber diaphragm and the toothpicks resting on it.

Discussion: When the rubber diaphragm is cut by the razor blade, the tension on the stretched rubber is released and will be pulled toward the outer edge of the jar. The toothpicks will move with the rubber much as they did in the water when the soap was placed in it. The surface "skin" of the water was broken by the soap and was pulled away from the center toward the sides of the pan. The water molecules, which are strongly held together, have been separated by the action of the soap molecules. For this reason, soap is used with water for washing clothes. Soap separates the water molecules from each other so that they will do a better job of getting into the tiny openings between the fibers of cloth to wash out the dirt.

41. Making a Soap Propelled Boat (Activity K-6)

Materials: Small cardboard box, soap, rubber band, and a large pan filled with water.

Procedure: Attach a stick of soap to one end of a small cardboard box with a rubber band as illustrated in Figure 5.15. Place the box and soap in the large pan of water. What happens?

Discussion: As the soap breaks the surface tension, the boat is propelled across the pan of water in the same manner as the toothpicks.

D. PHYSICAL PROPERTIES OF WATER

1. Liquids Are Difficult to Compress (Demonstration 3-6)

Materials: Glass bottle and a rubber stopper.

Procedure: Fill a glass bottle to the brim with water and try to compress the water by placing a cork or rubber stopper in the mouth of the bottle. What happens?

Discussion: The water will be forced out of the bottle by the stopper because it cannot be compressed.

2. Liquids Can Change Shape (Demonstration K-6)

Materials: Several jars of various sizes and shapes, ink, and water.

Procedure: Pour a few drops of ink into a jar of water to color it. Ask the children to observe what happens to the shape of the liquid water when it is poured from one jar to another.

Discussion: The shape of the liquid water will take the shape of the container into which it is poured.

3. Liquids Will Evaporate (Activity K-6)

Refer to Chapter V, Section C, Activity No. 6.

4. Liquids Will Freeze (Activity K-6)

Refer to Chapter V, Section C, Activity No. 11.

5. Liquids Will Expand When Heated (Activity K-6)

Refer to Chapter IV, Section E, Activity No. 1, "Water Thermometer."

6. The Volume of a Liquid Does Not Change (Activity K-6)

Materials: Glass jar with screw on lid, water, and ink.

Procedure: Fill a glass jar with water and add a few drops of ink to color the water. Screw the lid on the jar tightly and allow the jar to remain undisturbed for several days. What happens to the amount of water in the jar?

Discussion: The amount of water in the jar will not change. The water cannot evaporate because the lid has been screwed on tightly. The volume of the water in the bottle will not change unless some is poured out, it is allowed to evaporate, or it is allowed to freeze.

7. Solids Are More Compressible Than Liquids (Demonstration or Activity K-6)

Materials: Block of soft pine wood, block of hard wood (maple or oak), piece of steel, and a pair of pliers.

Procedure: Using a pair of pliers, squeeze a block of soft pine wood. Squeeze a piece of hard wood and a bar of steel. Can you compress them?

Discussion: The soft pine wood will compress easily between the jaws of the pliers. The hard wood will prove more difficult to compress whereas the steel bar will not noticeably compress at all. Solids are more compressible than liquids.

8. Solids Keep Their Shape (Demonstration or Activity K-6)

Materials: Block of wood and several glass containers of various sizes and shapes.

Procedure: Place the block of wood in several containers of various shapes and sizes in the same manner as done with the water in Demonstration 2 of this section. What happens to the shape of the block of wood?

Discussion: The block of wood retains its shape. It will not change its shape unless it is broken into smaller pieces or changed by wearing. The shapes of solids are rigid and they will not change shape under normal circumstances.

9. Solids Expand When Heated (Demonstration 3-6)

Materials: Glass bottle, metal washer, alcohol burner or hot plate, and a pair of forceps or pliers.

Procedure: Select a metal washer which will just fit through the mouth of a glass bottle. Hold it in the grips of a pair of forceps or pliers and heat it over a flame or on an electric hot plate until it is *red hot*. Attempt to pass the red hot washer through the mouth of the jar. What happens?

Discussion: The washer expands from the heat and will not pass through the mouth of the jar.

Figure 5.15

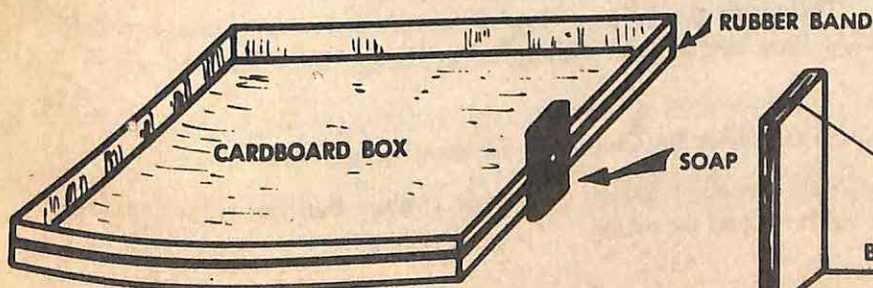
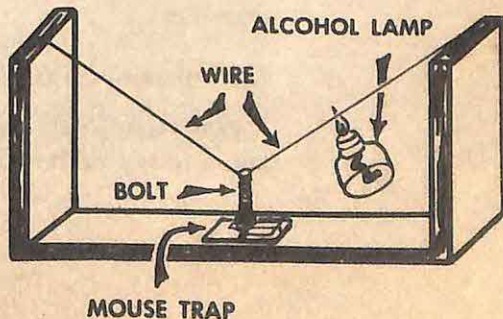


Figure 5.15a



10. Solids Expand When Heated (Demonstration 3-6)

Materials: Wooden bracket, length of thin bare copper wire, two nails, steel bolt, a mouse trap, and an alcohol burner.

Procedure: Assemble the above equipment as illustrated in Figure 5.15a. The weight of the bolt should be enough to hold the wire taut. Arrange the bolt in a position slightly above the triggering mechanism of the mouse trap. Heat the wire with the alcohol burner or other heat source available to you. What happens?

Discussion: The heat from the flame causes the wire to expand, become longer, and sag slightly, causing the bolt to trigger the mouse trap. This demonstration will illustrate the concept of expanding solids and create a lot of anticipation on the part of the students as well. Before trying this demonstration, be sure the wire will expand enough to trip the mouse trap. The wire will only expand so much and no more.

11. The Volume of a Solid Tends to Remain the Same (Activity 3-6)

Materials: Block of wood, brick, piece of iron or steel, spring scale (calibrated in ounces and pounds), string, and a ruler.

Procedure: Have a group of children accurately measure the weight and dimensions of each solid object above and record these weights and measurements. Place the objects in a safe place where they will not be disturbed. Have the children make another accurate measurement of the weights and dimensions of these objects a week later and again in another week. Have them record these weights and measurements and compare them with the previous week's measurements. How do the measurements compare? How much do the weights and measurements change from week to week?

Discussion: The weights and dimensions of the solid objects will not show any noticeable change. The volume will stay the same unless the solid is broken, worn, or heated. The children, however, may discover that it is difficult to measure things accurately. This might be a good time to introduce the concept that measurements are approximations. The accuracy of any measurement is dependent on the tool used, the size of the object being measured, and the person doing the measuring.

12. Gases Are Easy to Compress and Change in Shape (Demonstration K-6)

Materials: Rubber balloon.

Procedure: Fill a rubber balloon with air and tie the neck of the balloon in a knot. Hold the balloon in both hands and knead it like bread dough. What do you observe about the air (gases) in the balloon?

Discussion: The air in the balloon can be compressed and its shape can be changed. Every time the balloon undergoes a change in shape, the air in it does too.

13. Volume of a Gas Can Be Changed (Demonstration 3-6)

Materials: Wide-mouthed gallon jar, large rubber balloon, adhesive tape, and a heavy rubber band or string.

Procedure: Cut a rubber diaphragm from a large rubber balloon and stretch it over the mouth of a wide mouthed gallon jar. Hold it in place with adhesive tape, a heavy rubber band, or a length of string. (For illustration, refer to Figure 4.14 of Chapter IV.) Force your fist slowly into the jar pushing down on the rubber diaphragm. What happens to the volume of air in the jar? What happens to the volume of air in the jar as you pull up on the diaphragm?

Discussion: The air is squeezed or *compressed* into a smaller space when the diaphragm is forced into the jar. As the diaphragm is pulled up the volume of the jar increases and the air expands.

14. Gases Expand When Heated (Demonstration 3-6)

Refer to Demonstration 12 of Section A, Chapter IV.

E. THE CHEMICAL PROPERTIES OF MATTER

1. The Arrangement of Molecules in a Liquid Makes Them Difficult to Compress (Demonstration 4-6)

Refer to Demonstration 2 of Section B of Chapter III.

Because the molecules of a liquid are arranged very close together, there is little space between them. Such a close arrangement of molecules resists compression.

2. The Arrangement of Molecules in a Liquid Allows Them to Change Shape (Demonstration 4-6)

Refer to Demonstration 2 of Section B of Chapter III.

The bonds between the molecules of a liquid are not as rigid as they are in a solid, which allows them to separate from each other more readily. As a liquid is poured from one container to another, the molecules roll over each other and rearrange themselves to conform with the rigid shape of the new container.

3. Molecules of a Liquid Move Fast When Heated and Slow Down When Cooled (Demonstration 4-6)

Materials: Gallon mayonnaise jar, ping pong balls, and a tank type vacuum cleaner.

Procedure: Fill the gallon mayonnaise jar with ping pong balls. Reverse the hose of a tank type vacuum cleaner so that the air is blown out of the hose instead of being sucked into the hose. Place the discharge end of the hose into the center of the ping pong balls as illustrated in Figure 5.16 and start the vacuum cleaner motor. What happens to the ping pong balls? What happens to the ping pong balls when the force of the air is slowed down after the motor has been turned off?

Discussion: The ping pong balls represent the molecules of a liquid. As the liquid is heated, the molecules become very active and break away from the surface of the liquid in the form of a gas. The ping pong balls (molecules) fly away from the inside of the jar as they are agitated by the forced air of the

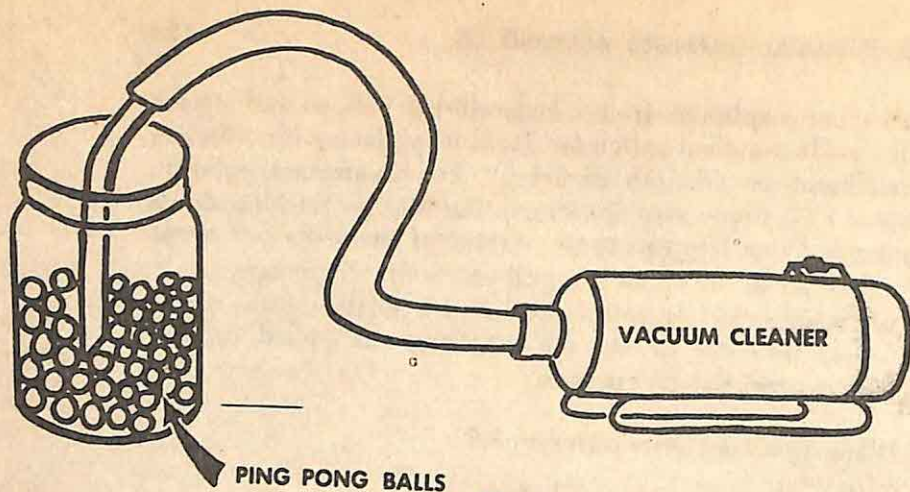


Figure 5.16

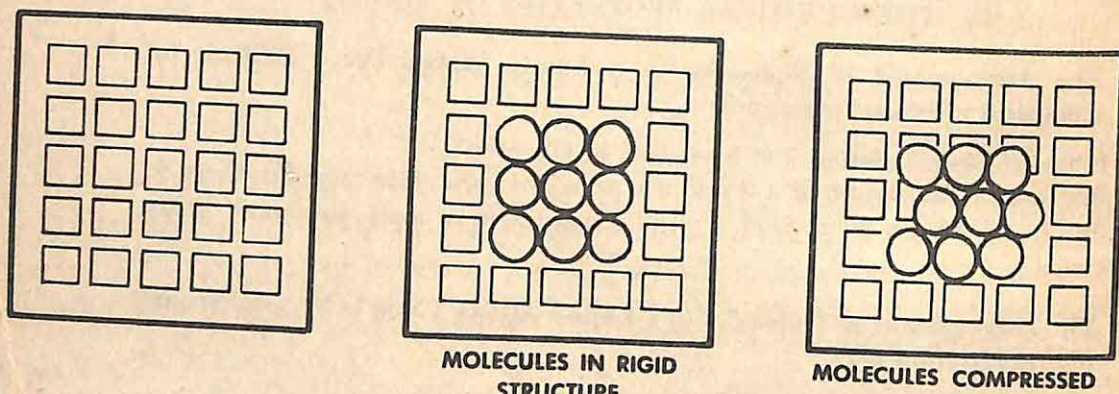


Figure 5.17

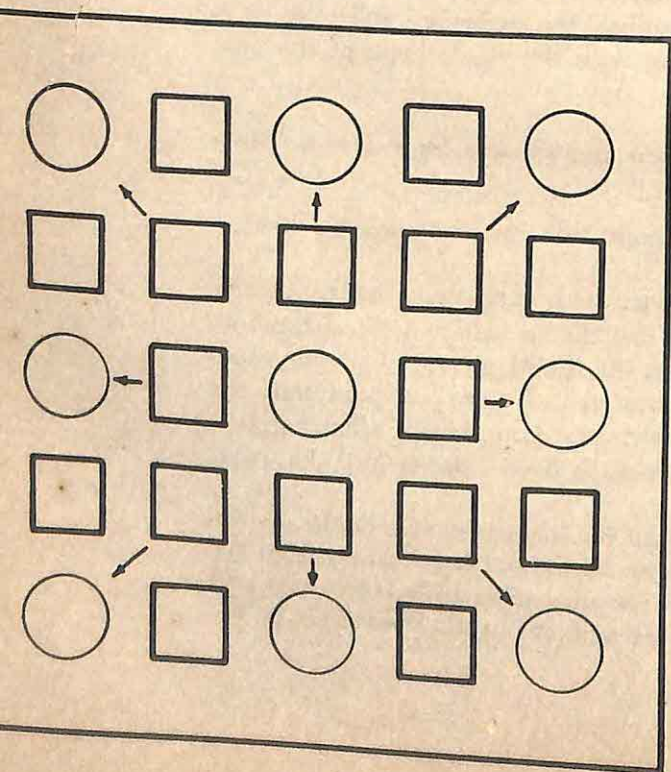


Figure 5.18

vacuum cleaner. They react in much the same manner as molecules of a liquid do when they are heated. By placing your hand over the open end (intake end) of the vacuum cleaner, the air flow is reduced and the ping pong balls slow down and finally settle in place as the vacuum cleaner motor is turned off. They react in much the same manner as molecules of a liquid do when they are cooled. If they are cooled to a low enough temperature, most liquids will freeze and form solids. *Ice* is an excellent example of this phenomenon.

4. The Volume of a Liquid Tends to Remain the Same (Demonstration 4-6)

Materials: Marbles and several glass jars of various shapes and sizes.

Procedure: Fill a glass jar with marbles and pour them from one container to the other. Eventually pour the marbles back into the first jar. Do they fill the jar again?

Discussion: If none of the marbles are lost, they will fill the first jar again. Correspondingly, a liquid will not lose its volume if none of it is lost from spilling or evaporation. If the temperature does not change, the volume will stay the same too. If heated, it will expand, and if cooled, it will contract.

5. Solids Are More Compressible than Liquids (Demonstration 4-6)

Materials: Nine ping pong balls and a sheet of corrugated cardboard.

Procedure: Cut some square holes in a sheet of corrugated cardboard as illustrated in Figure 5.17(a). These holes should be so arranged that, when the ping pong balls are placed over them, the balls will touch each other. Arrange nine ping pong balls in the holes as illustrated in Figure 5.17(b). Have the children observe the space between the ping pong balls. Have the children notice the size of the square formed by the ping pong balls. How could the ping pong balls (representing molecules) be arranged to compress the square?

Discussion: If the ping pong balls (molecules) were arranged in the manner illustrated in Figure 5.17(c), the square would be compressed. Solids can be compressed, too, by squeezing or compressing the rigidly arranged molecules so that they fill in the inter-molecular spaces. The space in wood is a good example of this.

6. Solids Expand When Heated (Demonstration 4-6)

Materials: Nine ping pong balls and a sheet of corrugated cardboard.

Procedure: Cut some square holes in a sheet of corrugated cardboard as illustrated in Figure 5.17(a). Arrange nine ping pong balls over these holes as illustrated in Figure 5.17(b). These ping pong balls represent molecules of a solid fixed in a rigid structure. As a solid is heated, what happens to it? What happened to the metal washer and the copper wire in Demonstrations 9 and 10 of Section D of this chapter?

Discussion: The metal washer and copper wire expanded when heated. The molecules of the metal became more active and began to move away from each other enough to prevent the metal washer from fitting into the mouth of the bottle. Expand the molecules in the cardboard rack as illustrated in Figure 5.18.

7. The Volume of a Solid Tends to Remain the Same (Demonstration 4-6)

Materials: Nine ping pong balls and a sheet of corrugated cardboard.

Procedure: Arrange nine ping pong balls in the holes of the corrugated cardboard as illustrated in Figure 5.17(b). The ping pong balls represent the molecules of a solid in a rigid structure. Will the volume of this solid structure of molecules change? If so, how?

Discussion: The size of the solid will not change unless certain things happen to it. If a solid (like a red brick) is struck with a hammer, a piece chips off. This is a mechanical way of separating the molecules and changing the volume. Remove one or two ping pong balls (molecules) to illustrate this. If the molecules are compressed, as they were in Figure 5.17(c), the volume will change. Will its weight also change? If the solid is heated it will expand and become larger. Expand the ping pong ball structure as illustrated in Figure 5.18. If any of these actions takes place, the volume of a solid will change.

8. Gases Are Easy to Compress, Change Size, and Change Shape

Materials: Gallon mayonnaise jar, half gallon peanut butter jar, six ping pong balls, and a tank type vacuum cleaner.

Procedure: Place six ping pong balls in a gallon mayonnaise jar. Reverse the hose of a tank type vacuum cleaner so that the air is blown out of the hose instead of being sucked into the hose. Place the discharge end of the hose into the large mayonnaise jar. The ping pong balls represent gas molecules which are moving at a rapid speed. What do you notice about the space between the moving balls in the jar? Do you think the molecules could be *compressed* or squeezed into a small space? Remove the six ping pong balls from the large mayonnaise jar and place them in the $\frac{1}{2}$ gallon peanut butter jar. Insert the discharge end of the vacuum cleaner hose into the peanut butter jar. Do the ping pong balls fit? Can they move around? What happened to the shape of the "gas" as it was placed in another smaller jar?

Discussion: The ping pong balls (gas molecules) will fit into the smaller jar. However, their activity is more limited, and the number of times they collide with each other is greater. This is due to the fact that they are in a much smaller space. *The molecules of gas can be compressed into a small space, i.e., the volume of gas can be changed, and the shape of the gas changes with the space of the container in which it is placed.*

9. Space Between Molecules (Demonstration 5-6)

Materials: Tall narrow olive jar, water, and alcohol.

Procedure: Half fill the olive jar with water. Fill the rest of the space in the jar with alcohol until the jar is almost, but not quite, full. Mark the total height of the liquids in the jar. Mix the two liquids together by shaking the jar. Allow the jar to stand for several minutes; then mark the height of the liquid once again. What do you observe?

Discussion: The height of the liquid is lower after the two liquids were mixed together. This is one example of how the molecules of one substance, alcohol in this case, can take up the space between the molecules of another substance, the water in this case. The next demonstration will help you to understand this better.

10. Space Between Molecules (Demonstration 5-6)

Materials: Gallon mayonnaise jar, ping pong balls, and b-b shot pellets.

Procedure: Half fill a gallon mayonnaise jar with ping pong balls. Notice the spaces between the balls. Pour several packages of b-b shot pellets into the jar over the top of the ping pong balls. Observe very closely what happens to the b-b shot.

Discussion: The ping pong balls and the b-b shot represent two kinds of molecules of different sizes. As the b-b shot is poured into the jar over the ping pong balls, they roll into the spaces between the ping pong balls without raising the height of the ping pong balls in the jar. Molecules of different substances of different sizes do the same thing. This accounts for the lowering of the liquid level of the solution of water and alcohol in the previous demonstration. Could this be the way salt and other substances are dissolved in water?

F. CHEMICAL REACTIONS

1. Producing Carbon Dioxide (CO_2) (Activity 4-6)

Materials: Glass jar, vinegar, and baking soda.

Procedure: Drop a teaspoonful of baking soda into a glass jar. Pour some vinegar over the top of the baking soda. What do you observe?

Discussion: As soon as the vinegar is introduced into the jar with the baking soda, a great mass of bubbles is produced. These bubbles are formed by the chemical reaction of vinegar and soda to form carbon dioxide.

2. Making a Soda-Acid Fire Extinguisher (Demonstration and Activity 4-6)

Materials: Plastic liquid soap squeeze bottle with a "snip off" plastic cap, string, baking soda, vinegar, and a small vial.

Procedure: Arrange the equipment as illustrated in Figure 5.19. Mix a solution in the ratio of one pint of water to three teaspoonfuls of baking soda. Fill the plastic bottle about $\frac{3}{4}$ full with the soda water. Fill the vial with vinegar and suspend it inside the jar as illustrated in Figure 5.19. Replace the plastic cap and invert the bottle. What happens?

Discussion: Carbon dioxide gas is formed in a chemical reaction with the vinegar and baking soda solution. The gas causes an excess amount of pressure inside the plastic bottle, forcing the baking soda-water solution out through the plastic cap in the same manner as does a soda-acid fire extinguisher. Soda-

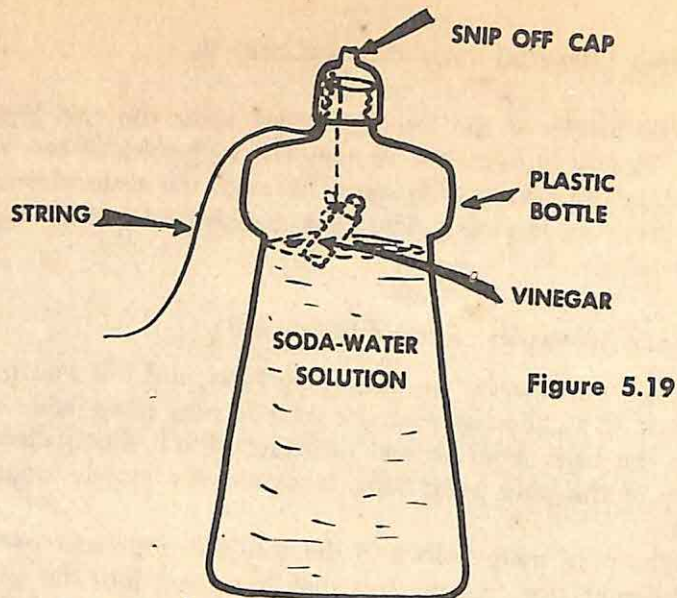


Figure 5.19

acid fire extinguishers are in great use in homes, factories, and schools because they are economical to maintain and easy to refill. The acid used in the commercial fire extinguisher is hydrochloric acid (HCl) and not vinegar. The soda solution is the same, and the chemical reaction produces CO_2 also. Demonstrate the use of a commercial soda-acid extinguisher out of doors. Before you do, however, get permission from your principal.

3. Producing Carbon Dioxide to Make Bread Rise (Activity 4-6)

Materials: Hot plate, coffee can top, flour, water, baking soda, and yeast.

Procedures: Mix $\frac{1}{4}$ cup of flour and $\frac{1}{2}$ teaspoon of sugar with water to make a flour dough. Mix $\frac{1}{4}$ cup of flour, $\frac{1}{2}$ teaspoon of sugar, water, and $\frac{1}{2}$ teaspoon of baking soda to make a flour dough. Mix together $\frac{1}{4}$ cup of flour, $\frac{1}{2}$ teaspoon of sugar, and $\frac{1}{2}$ teaspoon of chopped up yeast dissolved in water. Place a sample of equal amounts of dough on the surface of the coffee can lid and cook on the hot plate. Be sure you remember which dough has the baking soda in it and which one does not. What happens? Why?

Discussion: The dough with the baking soda rises to almost twice its original height, due to the production of carbon dioxide gas, which forms bubbles inside the dough to make it rise and become light and fluffy. The plain flour and water dough did not rise noticeably but became hard and crusty. The flour containing yeast will also rise. The yeast is a one cell plant producing enzymes as it grows, which causes the fermentation of the sugar in the dough. The enzyme oxidizes part of the sugar molecules into carbon dioxide and alcohol. The heat drives off the alcohol and carbon dioxide, leaving holes behind in the dough.

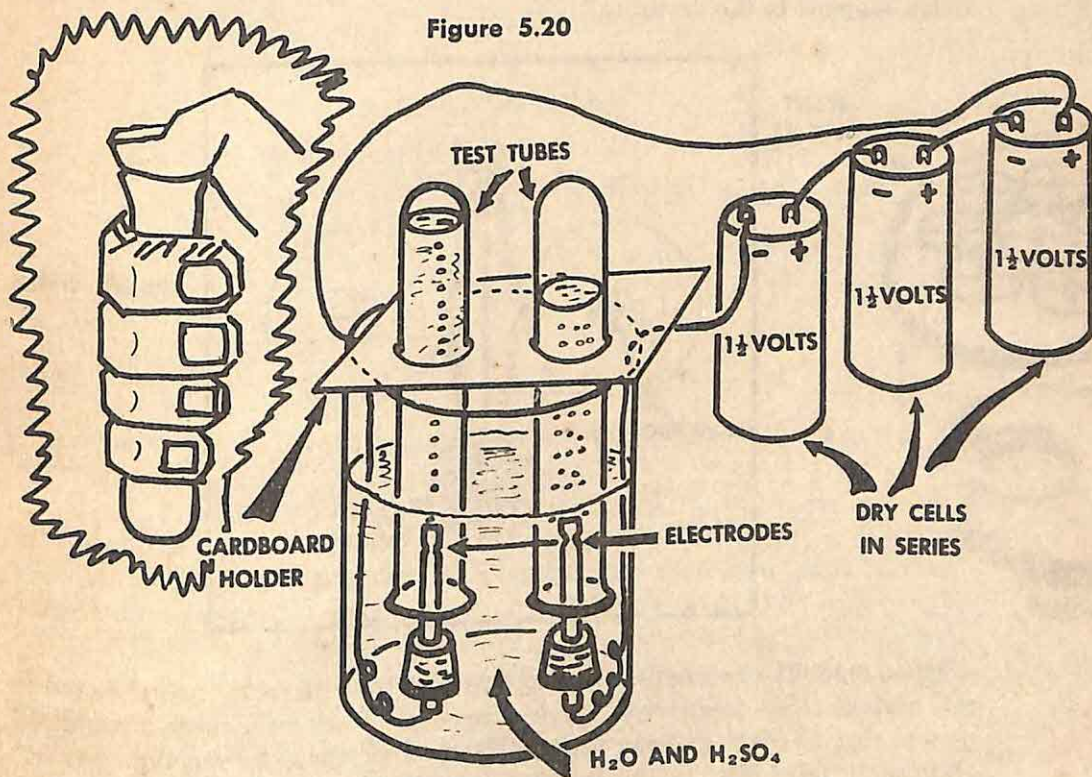
4. Electrolysis of Water (Demonstration 4-6)

Materials: Wide mouthed glass jar, copper wire, two platinum or carbon electrodes, two test tubes, three dry cells, a strip of cardboard, and diluted sulfuric acid (H_2SO_4).

Procedure: Assemble the above equipment as illustrated in Figure 5.20. Platinum electrodes work best for this demonstration. A pair of platinum electrodes can be purchased from any scientific supply house for about \$2.50. The investment is well worth the price, for they will last for years if properly cared for. Carbon rods from the center of old dry cells can be used, too; however, the chances of success are not as great.

Fill the glass jar $\frac{3}{4}$ full with water. Then fill each test tube with water and place your thumb over the opening as illustrated in Figure 5.20. Invert the test tube and insert the tube below the surface of the water. Release your thumb and lean the test tube against the inside of the jar, resting the open end on the bottom of the jar. Follow the same procedure with the second test tube. Insert the end of each test tube in the cardboard holder as illustrated in Figure 5.20. Slip the test tubes over the submerged electrodes as shown. Add an ounce of dilute sulfuric acid to the water. Connect three $1\frac{1}{2}$ volt dry cells ($4\frac{1}{2}$ volts) in series and observe the ends of the electrodes.

Figure 5.20



Discussion: Tiny bubbles start to form on each electrode. The bubbles form more rapidly on one electrode than on the other. After a few hours, one test tube will have twice as much gas as the other. Refer to the chemical formula of water, H₂O. In which test tube do we find hydrogen? Which one has oxygen? The formula (H₂O) tells us that water is made up of twice as much hydrogen (H) as oxygen (O). The test for hydrogen is to place a glowing splint in the tube. If a loud "pop" occurs, the gas is hydrogen. If the splint merely glows

brighter, the gas is oxygen. Hydrogen is *explosive*, thus accounting for the "popping" noise. Great care should be taken when handling hydrogen gas.

5. Electron Transfer of Atoms in Chemical Reactions (Demonstration 4-6)

Materials: Round or horseshoe magnet, two thumb tacks, a sheet of cardboard, and rubber cement. (See Figure 5.20a.)

Procedure: Glue a cardboard disk onto a horseshoe or round magnet. The round circles with signs represent the eight protons in the nucleus of the oxygen atom. Draw two hydrogen atoms with a single proton in each on a sheet of cardboard 12 inches square. Draw a circle around each proton to represent the orbital path of the electron of each hydrogen atom. Place one steel thumb tack on the orbital path of each hydrogen atom as shown. Label the hydrogen and oxygen atoms. Place the oxygen nucleus (magnet and cardboard dish) on the sheet of cardboard and move it between the two hydrogen atoms so that it passes close to and between the two electrons (thumb tacks). What happens to the electrons?

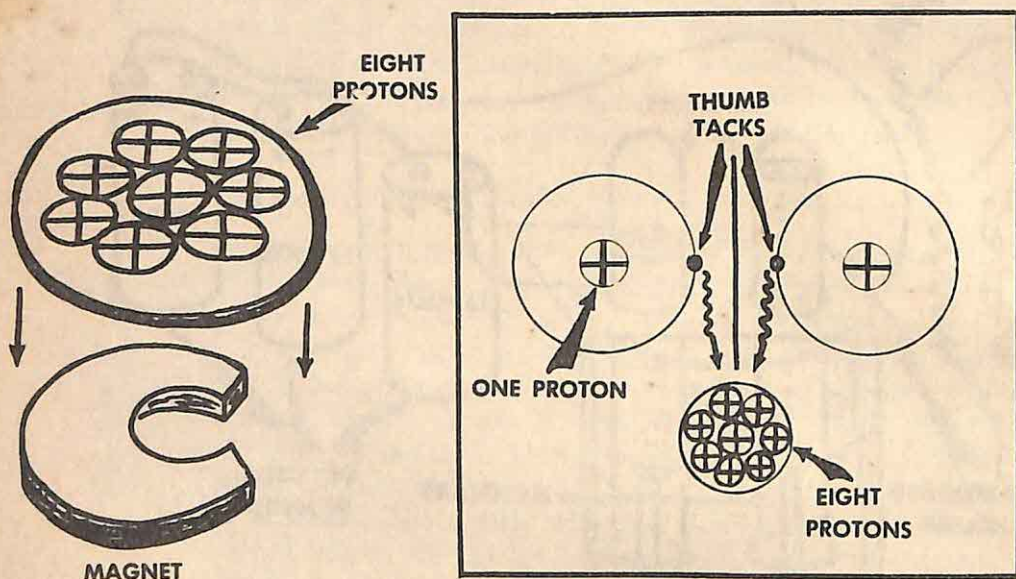


Figure 5.20a

Discussion: The two hydrogen electrons (steel thumb tacks) are attracted to the oxygen atom (magnet). The hydrogen electrons have been *transferred* to the oxygen atom to form water (H_2O). This chemical reaction involves *electron transfer*. The reason for the electron transfer in this chemical reaction may be seen in the following simple explanation. The hydrogen atom has one proton and one electron. The oxygen atom has eight protons, eight neutrons, and eight electrons. The protons of each atom have a positive charge. They are capable of attracting negatively charged electrons. For some reason the eight protons of the oxygen atom have the power to attract two more electrons into orbit around its nucleus. The hydrogen atom, however,

cannot attract any more electrons with its single proton. In the presence of heat, the single oxygen atom will attract the single electron of two hydrogen atoms. This sharing of electrons binds the one oxygen atom and the two hydrogen atoms together to form water (H_2O).

There are some limitations imposed upon this demonstration, which the teacher should point out to the children before conducting it. It should be noted that the eight electrons of the oxygen atom are not shown or used and the eight neutrons are not shown in the nucleus. This is for simplicity. The important parts involved are the two electrons of the hydrogen atom and the protons of the oxygen atom. It should also be noted that not all chemical reactions involve the *transfer of electrons* or the *sharing of electrons*.

The actual chemical reaction can be witnessed in Demonstration 4 above when the hydrogen gas is heated with a flame and creates a "pop" as it unites with the oxygen in the air.

G. THE CHEMISTRY OF FIRE

1. Fire Needs Air to Burn (Demonstration K-6)

Materials: Glass jar and candle.

Procedure: Light a candle with a match and place a glass jar over the candle and flame. Observe what happens to the flame.

Discussion: The flame slowly dies out from a lack of a sufficient amount of oxygen to support combustion. The flame *does not* use up all the oxygen in the jar as often believed.

2. Fire Needs Air to Burn (Demonstration 3-6)

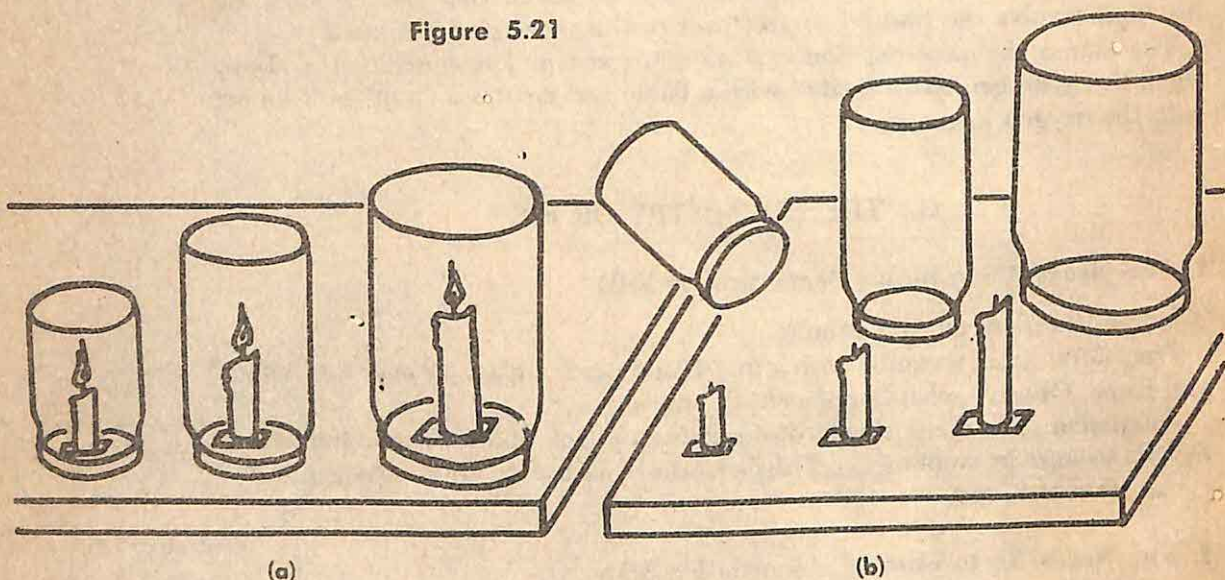
Materials: Three glass jars of graduated sizes, three candles, matches, and a stop watch.

Procedure: Light each candle with a match and invert a jar over each candle as illustrated in Figure 5.21(a). Have a student help you place the third jar over the candle so that the candles are covered at the same time. Using a stop watch or a watch with a second hand, record the time it takes for each flame to go out. Which candle flame goes out first? Why? Repeat the demonstration as follows: after each flame goes out lift the two largest jars from over their candles and place them mouth down on the table as illustrated in Figure 5.21(b). Lift the smallest jar from over its candle and hold it in your hand. *Do not* place it mouth down on the table. Carry out this operation as you are talking to the children without drawing attention to your exact procedure. You might say something like this: "Let us try the same experiment again as scientists do. Scientists repeat their experiments many times before they are satisfied with the results." Now light the candles and have a student help you invert the jars over the candle flames once again. Have the student place the smallest jar over the flame as you place the two larger jars over the flames of their candles. Be sure to keep the open ends of these jars

down as they are placed over the flames. Record the time it takes each flame to go out. What happens? Why?

Discussion: During the first trial of the demonstration the flame under the smallest jar will go out first, then the flame under the next largest jar, and finally the flame under the largest jar. The explanation for this phenomenon is easily discovered by the children. The larger the jar, the more oxygen it has in it to sustain combustion. During the second trial of the same demonstration the results are radically different. This time the flames in the two larger jars are extinguished in a shorter period of time or possibly before that in the

Figure 5.21



smallest jar. Challenge the children to tell why it happened. The reason can be seen in the procedure used in conducting the demonstration the second time. Figure 5.21(b) shows the two largest jars mouth down on the table and the smallest jar with its mouth above the table top so that fresh air can enter and the heavy carbon dioxide gas can escape. Some fresh air will get into the larger jars, too, thus accounting for the short lived flame. The teacher will have to rehearse this demonstration, trying out various size jars beforehand to get the right combination of jar sizes for the desired results.

3. Some Materials Burn: Others Do Not (Demonstration K-6)

Materials: Glass jar, steel nail, wooden match, paper, cloth, plastic, a stone, a piece of brick, a candle, and a pair of forceps or pliers.

Procedure: Light a candle with a match and test the various materials to see which will burn.

Discussion: The wooden match, paper, cloth, and plastic burn when placed in the candle flame. The glass jar, steel nail, stone, and piece of brick do not burn. The materials which burned are known as fuels.

4. Fire Needs Fuel and Heat to Burn (Demonstration 3-6)

Materials: Wood, liquid alcohol burner, and bunsen burner or portable propane gas burner.

Procedure: Display the three kinds of fuel: solid (wood), liquid (alcohol), and gas. Using a match, light each fuel. Which fuel takes the least amount of time to begin burning?

Discussion: The gas ignited almost instantaneously when placed near the lighted match. The liquid alcohol ignited faster than the wood, but slower than the gas. All three fuels, however, needed heat to get started.

5. A Flame Gives Off Heat in All Directions (Demonstration 3-6)

Materials: Candle, matches, and a sheet of notebook paper.

Procedure: Light the candle and place a strip of notebook paper about two or three inches from the flame at a point at which the paper will just start to burn (where the paper begins to turn brown). Repeat this procedure at various points around and above the flame. Does the paper begin to burn at these other points too?

Discussion: The paper will begin to burn at any point around it if held close enough to (but not touching) the flame. It should be noticed that the hottest part of the flame is directly over the flame. Why?

6. A Flame Gives Off Light in All Directions (Demonstration 3-6)

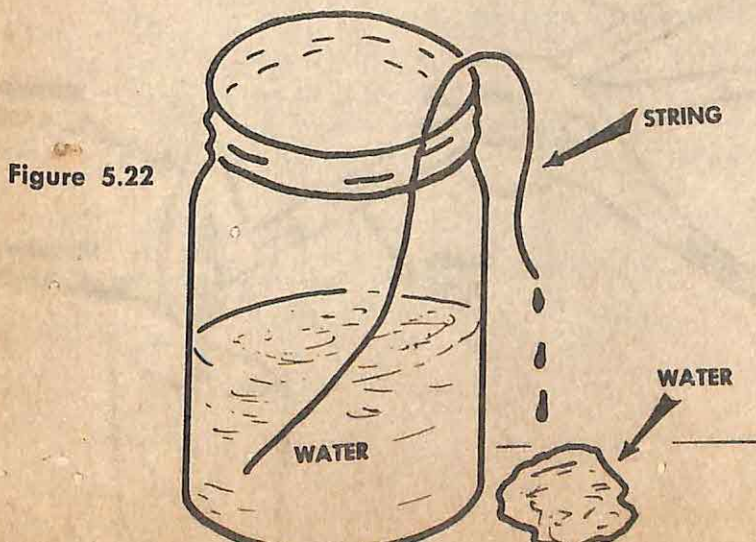
Materials: Candle, matches, and a sheet of white cardboard.

Procedure: Darken the room and light the candle with a match. Hold a white card or sheet of white paper in a vertical position about six inches from the flame. Does the candlelight reflect from the white card? Shift the position of the white card around the flame. Does the card reflect the candlelight at these other positions?

Discussion: The flame of the candle sends out light in all directions around it. This light is then reflected by the white card at the various positions.

7. Liquids Climb Up a String (Activity 3-6)

Materials: Glass jar, six inch length of cotton string, and ink.



Procedure: Half-fill the glass jar with water and add a few drops of ink to color it. Assemble the equipment as illustrated in Figure 5.22, allowing one end of the wet string to remain in the water overnight. What do you observe happening at the other end of the string the next day?

Discussion: The water will move up the string by absorption and drip from the other end. The wick of a candle performs the same function with the melted wax. The melted wax moves up the porous wick, is heated, vaporizes, and burns.

8. The Wick of the Candle Carries the Melted Wax to the Flame (Demonstration 3-6)

Materials: Candle, matches, black pepper, and a magnifying lens.

Procedure: Light the candle with a match and allow it to burn until the wax is well melted around the wick. Sprinkle some ground black pepper into the pool of liquid wax on the candle top and observe it with the aid of a magnifying glass. Do not get too close to the flame.

Discussion: As the candle wax melts, a movement of the wax toward the wick can be detected. The movement of the black pepper specks will reveal this. The cloth wick is absorbing the liquid wax in the same manner as the string absorbed the water in Activity 8 above.

9. A Flame Is Made Up of Hot Gases (Demonstration 3-6)

Materials: Wax candle, matches, glass tubing, and a spring type clothes pin or pair of pliers.

Procedure: Light the candle and place one end of the glass tubing into the center of the flame (inner zone) near the wick as illustrated in Figures 5.23. Strike a match and hold the flame at the opposite end of the glass tubing. What do you observe?

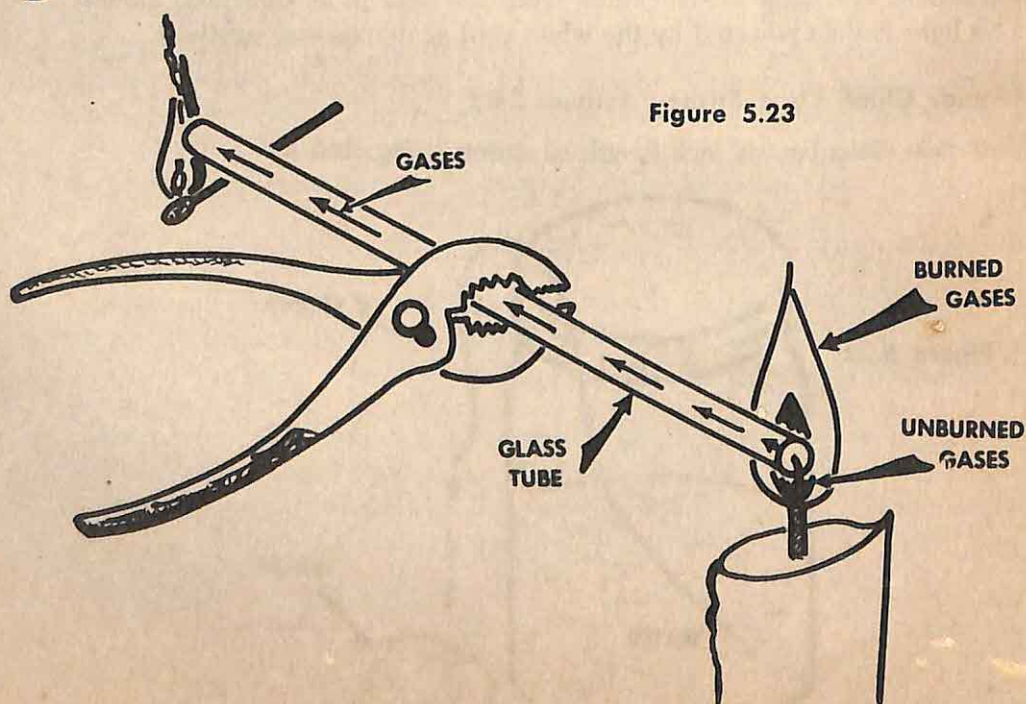


Figure 5.23

Discussion: This demonstration will take some practice on the part of the teacher to gain full results. The white vaporized unburned fuel from the wax candle will rise up the glass tube and come out of the opening at the opposite end. If the glass tubing is held at the right angle, this can be accomplished. The flame from the match will ignite the vaporized fuel. A flame is made up of gases which will burn when heated.

10. Liquid Fuel Must Vaporize Before Igniting (Demonstration 3-6)

Materials: Alcohol burner, matches, glass tubing, and a spring type clothes pin or pair of pliers.

Procedure: Feel the wick of the alcohol burner. How does it feel? Set up the equipment as illustrated in Figure 5.24 and follow the same procedure as outlined in Demonstration 9 above.

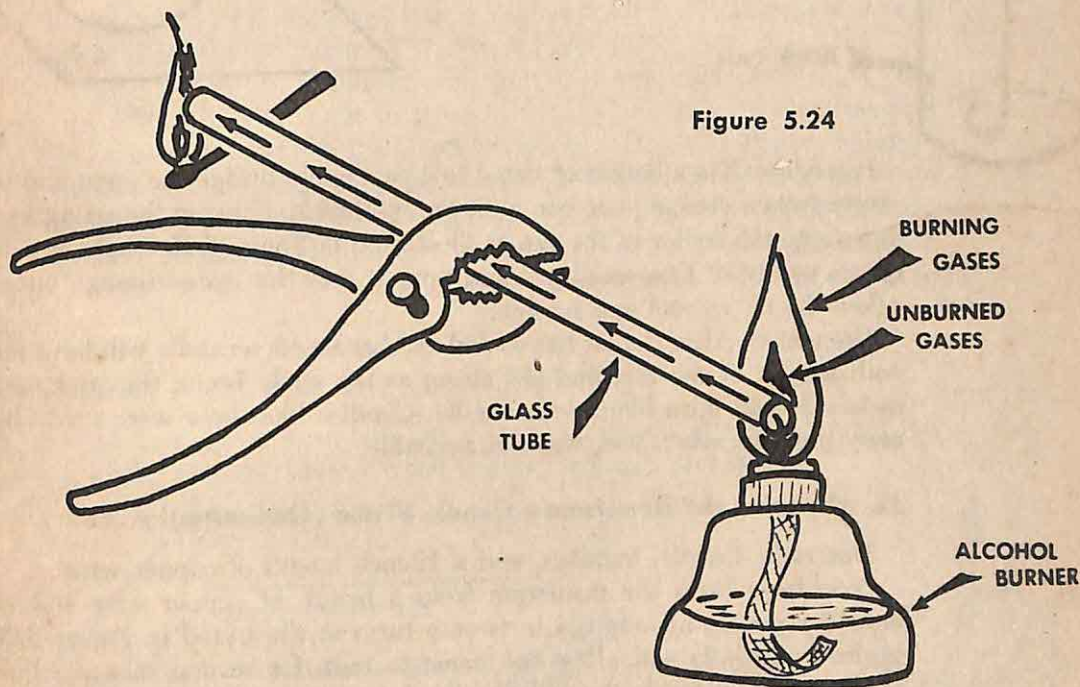


Figure 5.24

Discussion: The wick of the alcohol burner feels wet. It is wet with alcohol, which it has absorbed from the reservoir of the burner. Alcohol vaporizes and the unburned gases rise up the glass tube and are ignited at the opposite end. The liquid fuel has been heated and transformed into a gas which burns. Liquid fuel must also be vaporized into a gas before it will burn.

11. Making a Candle of Cooking Fat and Butter (Activity 3-6)

Materials: Rendered bacon fat or butter, six ounce frozen orange juice can, a small pot, string, tooth pick, and an electric hot plate.

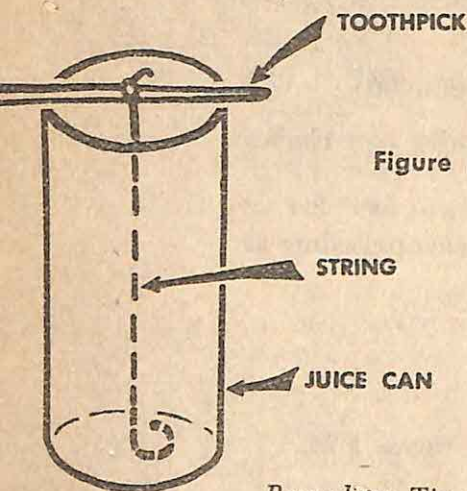


Figure 5.25

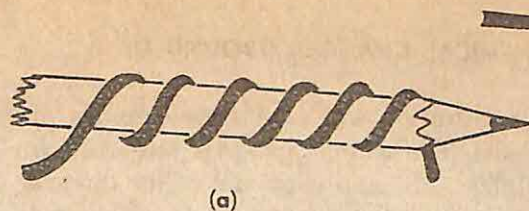
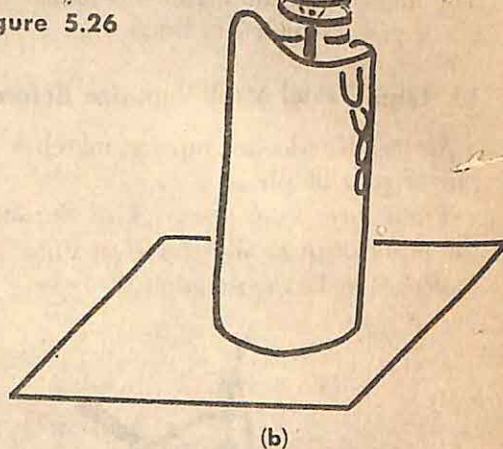


Figure 5.26



Procedure: Tie a length of string to a toothpick. Bridge the open end of the empty frozen orange juice can with the toothpick, allowing the string to hang down into the center of the can as illustrated in Figure 5.25. Melt some bacon grease or butter in a small pot and pour it into the frozen orange juice can. Allow the fat to cool and harden.

Discussion: After the fat has cooled and hardened, a candle will have formed with the fat as the fuel and the string as the wick. Ignite the wick, using a match. It will burn like a wax candle. Candles like these were made by the early pioneers when wax was not available.

12. Absorbing the Heat from a Candle Flame (Demonstration 3-6)

Materials: Candle, matches, and a 12-inch length of copper wire.

Procedure: Strip the insulation from a length of copper wire and coil it around a pencil, making ten to twenty turns as illustrated in Figure 5.26(a). Ignite the candle and allow the flame to burn for several seconds. Pull the pencil out from inside the coil of wire. Lower the coil of wire over the flame slowly until the flame is completely surrounded by the wire coil as illustrated in Figure 5.26(b). What happens to the flame? Why?

Discussion: The flame will be considerably reduced in size or may be completely extinguished. The copper wire absorbed heat from the flame and lowered the temperature enough to either reduce the size of the flame or to extinguish it completely.

13. Metal Absorbs Heat (Demonstration 3-6)

Materials: Handkerchief, penny, and a match.

Procedure: Place a lighted match in contact with a handkerchief. What

happens to the handkerchief? Wrap a penny tightly in the handkerchief. Place the lighted match next to the surface of the handkerchief and penny. What happens?

Discussion: The lighted match will burn a hole through the cotton cloth. The lighted match will not burn a hole through the handkerchief when it is backed with the copper penny. The copper penny absorbs heat from the burning match and lowers the temperature enough to prevent the handkerchief from igniting. The *kindling temperature* of the handkerchief is never reached.

14. Boiling Water in a Paper Cup (Demonstration 3-6)

Materials: Alcohol burner, two paper containers, ring stand, 4 by 4 inch square of wire mesh, and water.

Procedure: Place an empty paper container over a lighted alcohol burner. What happens to it? Fill another paper container with water and place it over the flame as illustrated in Figure 5.27. What happens?

Discussion: The paper container without the water inside will burn. The paper container with the water in it will not burn because most of the heat from the flame is absorbed by the water in the container, and the temperature of the paper never gets high enough for it to ignite. The *kindling temperature* of the paper is never reached. The water can be brought to a boil without the container ever burning. *Note:* Be sure to use a paper container with a smooth bottom as illustrated in Figure 5.27. Be sure *not to use* a wax covered container.

15. Vaporizing Fuels by Heating (Demonstration 4-6)

Materials: Two coffee cans with lids, several blocks of pine wood, some soft coal, hot plate, matches, several wood splints, hammer, and nail.

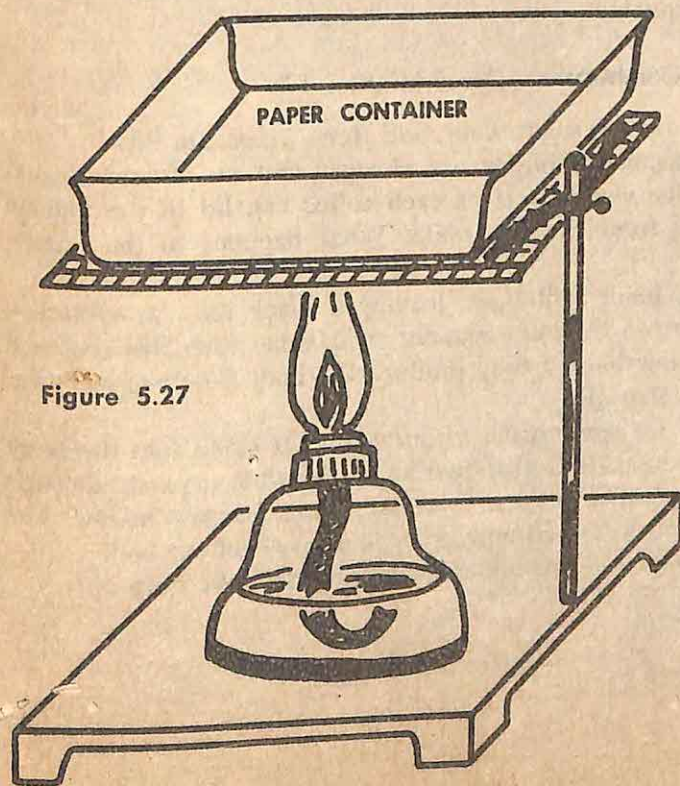


Figure 5.27

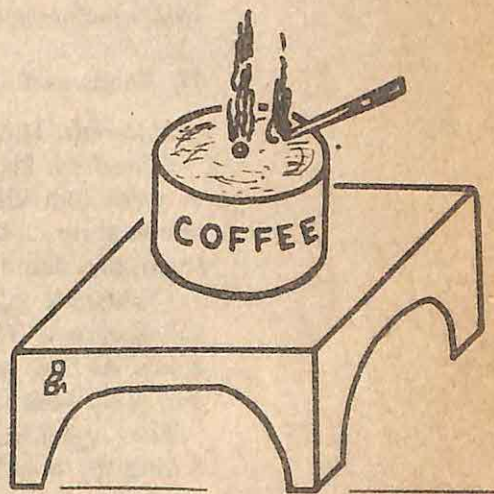


Figure 5.28

Procedure: Fill one coffee can with the pine wood and the other coffee can with soft coal. Put the lid on each can and punch a small hole in the center of each lid, using a hammer and nail. Place one of the coffee cans on a hot plate and heat it to the highest temperature available. What happens?

Discussion: As the wood or soft coal is heated, smoke begins to rise from the small hole punched in the center of the lid. As the pressure builds up inside the can from the unburned gases (smoke), a stream of smoke is forced out of the hole at an increasing speed. If a lighted match or wood splint is placed near the column of smoke it will ignite and burn with a continuous flame as illustrated in Figure 5.28. In order for a fuel to burn, it must first be transformed into a *vapor or gas*. Solid and liquid fuels can be *vaporized* by heating them. As the fuels are heated, the *molecules* become very active and break away, creating a vapor or gas. Smoke is evidence of unburned gases. As more heat is added, the gases ignite and burn in a continuous flame.

The resulting products in the two cans are *coke* from the soft coal, and *charcoal* from the pine wood. These products contain high concentrations of carbon molecules, resulting from the escape during combustion of the other molecules which made up the soft coal and pine wood. A sticky substance known as coal tar can be found on the inside of the cans and lids. This is another by-product of making coke and charcoal.

16. A Flame Produces Water (Demonstration 3-6)

Materials: Candle, match, and a slate board.

Procedure: Light a candle and hold the flame next to the slate board. Observe the surface of the slate very carefully.

Discussion: The area of the slate adjacent to the flame will appear slightly darkened as it would if it had been moistened with a damp sponge. What is actually happening is that the flame is producing water vapor in the process of combustion. The water vapor is condensing on the cool slate, forming a wet spot which evaporates quickly.

17. Foods as Fuel for Combustion (Demonstration 3-6)

Materials: Hot plate, butter, sugar, flour, and three coffee can lids.

Procedure: Place a teaspoon of butter, one of sugar, and one of flour in each of three individual coffee can lids. Heat each coffee can lid to the highest temperature obtainable from the hot plate. What happens to the butter, sugar, and flour?

Discussion: All three foods will burn, leaving a black ash-like substance called carbon. They burn in the same manner as do other fuels like coal and wood. As they burn in our bodies, they produce the body heat necessary for our many body cells to stay alive.

The oxygen required for *combustion* in our bodies is taken into the body during the breathing process. It is absorbed by the blood that passes through the lungs and is carried in arteries and veins throughout our bodies. The chemical reaction of combustion can now occur in all parts of our bodies.

If combustion is occurring in our bodies, then why don't we burn up?

First of all, the chemical reaction of combustion is going on at a slower rate in our bodies; this produces less heat. Second, the great amount of water in our bodies helps to cool our bodies. Third, our body radiates (gives off) a lot of heat in several ways, through our skin, breathing, excretion of waste material, and perspiration. Fourth, the vitamin B which we obtain from some of our foods acts as a regulator to speed up or slow down the chemical reaction of combustion in our bodies. There are other reasons, too, which need not be discussed at this time.

18. Chemicals Needed to Build Strong Bones (Activity 3-6)

Materials: Leg bone of a cooked chicken, glass jar with screw on lid, and vinegar.

Procedure: Fill a jar with vinegar, submerge a leg bone of a cooked chicken in it, and seal the jar with a screw on lid. After ten days, remove the bone and try to break it in half by bending it with your fingers.

Discussion: The bone will not break because it has become very soft and pliable—like rubber.

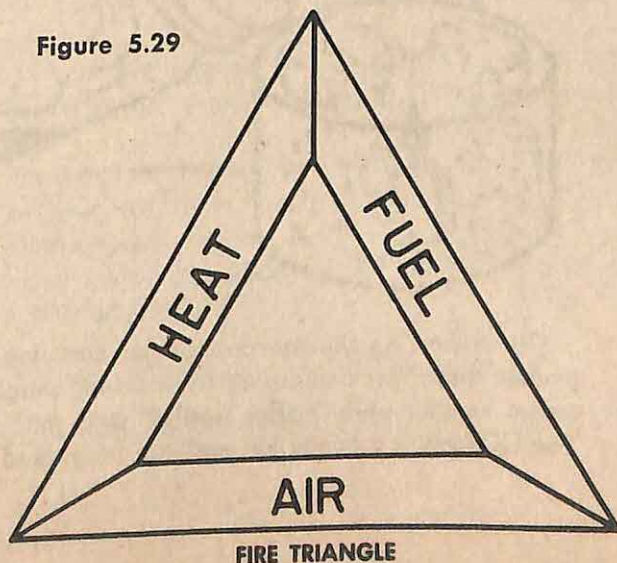
A chemical reaction of the vinegar (acetic acid) with the calcium in the bone has removed this calcium from the bone. Calcium is the strength building substance of our bones. Without calcium our bones would be soft as rubber. Milk is one of the foods which contains calcium for building strong bones. All that is left in the bone is protein, which makes up cartilage. A bone starts out as soft cartilage and later becomes calcified (hardened) into bone. The lack of calcium in our bones can result in soft bones, a disease known as *rickets*. What would happen if you put the soft bone in milk?

19. The Fire Triangle (Demonstration 3-6)

Materials: Three strips of cardboard with flannel backing and a flannel board.

Procedure: Letter each strip of flannel backed cardboard as illustrated in Figure 5.29. Arrange the three strips on the flannel board to form a triangle as shown.

Figure 5.29



Discussion: This is known as the *fire triangle*. Fire needs *heat*, *fuel* and *air* to burn. If any one of the three sides of the triangle is removed, the triangle is destroyed. If any one of the ingredients necessary for a fire is removed, the fire will not burn. The job of firemen is to remove one or more parts of the fire triangle in order to extinguish a fire.

20. Removing Heat from the Flame, Using Water (Demonstration K-6)

Materials: Pie tin, paper, matches, and jar of water.

Procedure: With a match, ignite a crumpled up sheet of paper in a pie tin. Pour some water from a jar over the flames. What happens?

Discussion: The flame was extinguished for two reasons. The cool water lowered the temperature of the fire and also helped to smother the flame.

21. Carbon Dioxide Gas Can Be Poured (Demonstration 4-6)

Materials: A peanut butter jar, a quart mayonnaise jar with screw on lid, baking soda, vinegar, a candle, and matches.

Procedure: Place a candle in the peanut butter jar as illustrated in Figure 5.30. Pour a few ounces of vinegar into the mayonnaise jar. Add a tablespoon of baking soda to the vinegar and screw on the lid of the jar about half way. This will allow some of the carbon dioxide gas to escape and prevent the build-up of pressure in the jar.

Light the candle in the peanut butter jar. Remove the lid from the mayonnaise jar and tip its open mouth over the peanut butter jar as illustrated in Figure 5.30. Do not allow the liquid at the bottom of the jar to pour out into the peanut butter jar.

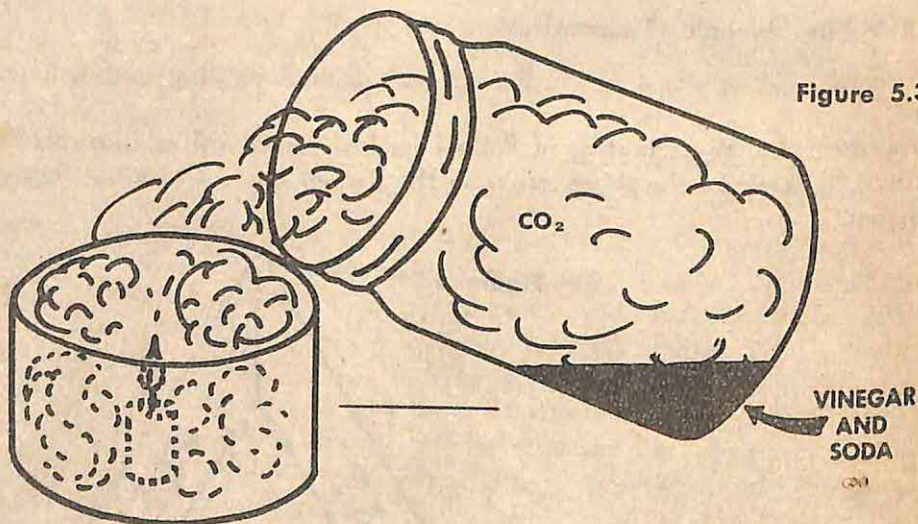


Figure 5.30

Discussion: As the mayonnaise jar containing CO_2 gas is tipped over the peanut butter jar containing the flaming candle, the flame of the candle becomes smaller and smaller until it goes out. Try lighting the candle again. The CO_2 gas is a heavy gas and can be poured from one container to another.

Even though it is invisible, try pouring the CO_2 gas from the peanut butter jar into another peanut butter jar containing another flaming candle. CO_2 gas is heavy enough to smother a fire by collecting around it and depriving the flames of oxygen necessary for combustion.

22. Using Carbon Dioxide Gas to Smother a Fire (Demonstration K-6)

Materials: Deep metal pot, gallon jar with screw on lid, sheet of paper, matches, vinegar, and baking soda.

Procedure: Pour a cup of vinegar into the gallon jar. Add about $\frac{1}{4}$ cup of baking soda and screw the lid on loosely. Crumple up a sheet of paper and drop it into the metal pot. Ignite the paper and pour the CO_2 gas into the pot over the flame. What happens?

Discussion: The CO_2 gas will extinguish the flame by depriving it of oxygen. The heavy gas collects in the pot, forming a blanket of gas which smothers the fire.

H. METHODS OF SEPARATING SOLUTIONS

1. Separating Solutions by Evaporation (Demonstration and Activity K-6)

Materials: Pyrex beaker or tin can, salt or sugar, and hot plate.

Procedure: Mix solution of salt and water or sugar and water. Heat the solution in a pyrex beaker or a tin can until all the water has evaporated. What is left in the container?

Discussion: A crust of salt or sugar will line the bottom and sides of the container. If sugar solution is used, care should be taken not to allow it to burn by removing the container from the hot plate before all the liquid has evaporated.

2. Separating Solutions by Evaporation and Flotation (Demonstration and Activity 3-6)

Materials: Pyrex beaker or tin can, hot plate, salt, pepper, water, and a spoon.

Procedure: Mix some salt and pepper together. How can they be separated? Pour the mixture of salt and pepper into a beaker of water. What happens to the salt? the pepper?

Discussion: The pepper floats on the surface of the water while the salt either sinks to the bottom or dissolves in the water. The pepper can be removed from the water by using a spoon. The salt can then be separated from the water by heating the solution on a hot plate and allowing the water to evaporate, leaving behind a residue of salt.

3. Separating Solutions by Filtering (Demonstration and Activity K-6)

Materials: Two glass jars, sawdust, paper towel or cotton cloth, water, and a rubber band.

Procedure: Half-fill one jar with water and add to it some sawdust. The sawdust floats. How can it be separated from the water? Place a paper towel or cotton cloth over the mouth of another jar, forming a pocket like depression with the paper or cloth inside the mouth of the jar. Hold the paper or cloth in place with a rubber band. Pour the solution of water and sawdust slowly into the pocket formed. What do you observe?

Discussion: The sawdust is trapped by the paper or cloth filter as the water flows through into the empty jar. This process is known as *filtering*.

4. Separating Solutions by Evaporation, Magnetism, Flotation and Filtering (Demonstration and Activity 3-6)

Materials: Sawdust, salt, iron filings, pyrex beaker, hot plate, magnet, glass jar, and water.

Procedure: Mix a teaspoon of sawdust, iron filings, and salt together. Pour this mixture into a jar half filled with water and stir. How can these substances be separated from each other?

Discussion: The iron filings can be removed from the solution with a magnet. The sawdust can be removed by flotation or filtering. The salt can be removed by the process of evaporation.

5. Separating Oil from Water (Demonstration 3-6)

Materials: Glass jar, water, oil, and a spoon.

Procedure: Half-fill a jar with water and add several ounces of oil. Screw the lid on the jar tightly and shake well. Allow the solution to stand for several minutes without being disturbed. What do you observe happening?

Discussion: The oil separates from the water by floating to the surface of the water. Oil is lighter than water and will float on water. The oil can now be poured off the top of the water or skimmed off with a spoon.

6. Separating Oil from Water (Demonstration 3-6)

Materials: Glass jar, water, oil, matches, and wood splints.

Procedure: Same as for Demonstration 5 above.

Discussion: The oil that has floated to the surface of the water can be removed from the water by igniting it with a match or wood splint.

I. TESTING CHEMICALS

1. Identifying Chemicals by Guess or by Test (Demonstration 4-6)

Materials: Salt, sugar, flour, baking soda, and a black sheet of paper.

Procedure: Display on a black sheet of paper a pile of salt, one of sugar, one of flour, and one of baking soda for the children to see. Ask the children to identify each white substance on the card. Which one is the salt? Which one is flour? How can you tell? How can you be sure?

Discussion: Usually the children will make many guesses; some will be

right, and some will be wrong. But they will all be guesses. The salt and sugar would be easy to identify if we could taste them. Tasting chemicals is very dangerous. One of the four white substances on the black card could be *arsenic* which looks like flour or sugar. Arsenic is a deadly poison and, if taken into the mouth, could result in death. Scientists cannot depend on guessing or tasting to identify chemicals. They must be sure in order to be safe. To be safe, scientists have invented ways of testing chemicals for identification purposes. It is these tests which will be studied in the next few demonstrations and activities.

2. Making and Testing with Acid Indicators (Activity 4-6)

Materials: Fresh beet, fresh red cabbage, cherry juice, grape juice, blue litmus paper, hot plate, two pyrex beakers, grape juice, orange juice, lemon juice, vinegar, and several jars.

Procedure: Slice a fresh beet and boil it in water until the water becomes red. Remove the beet slices, pour the juice into a jar, and cover with a lid. Slice up a section of red cabbage and boil it in water until the water turns purple. Remove the cabbage, place the purple juice in a jar, and cover it with a lid. The beet juice, red cabbage juice, grape juice, cherry juice, and blue litmus paper can all be used as acid indicators. Mix a teaspoon of any one of the liquid indicators with a glass of water when an acid test is desired. Drop a few drops of *citric acid* (lemon, orange or grapefruit juice) or *acetic acid* (vinegar) into the liquid indicators and observe what happens. Place a few drops of one of these acid substances on a strip of blue litmus paper. Observe what happens.

Discussion: When acid is added to the liquid indicators, their color fades or becomes lighter. The blue litmus paper will turn red. These are tests for acids.

3. Test for Bases (Activity 4-6)

Materials: Pint jar, water, beet juice, ammonia, vinegar and a medicine dropper.

Procedure: Half fill a pint jar with water. Using a medicine dropper, add a few drops of beet juice to the water to give it a slightly reddish tint. Pour an ounce or so of ammonia into the jar of water. Do you observe any change in the color of the water? Next pour some vinegar into the ammonia water until you observe a change in the color of the water.

Discussion: The color of the water will change to a very dark purple color when the ammonia (a base) is added to the water. This is a test for chemicals known as bases. When the vinegar (an acid) is then added to the water containing the ammonia, the color again changes back to a light reddish tint. This is an indicator for testing the presence of acids.

4. Soil Tests (Demonstration and Activity 3-6)

Materials: Blue and red litmus paper and several soil samples.

Procedure: Moisten the various soil samples collected and test them for acids and alkalies by using red and blue litmus paper.

Discussion: If the blue litmus paper turns red, the soil is an acid soil. If the red litmus paper turns blue, it is an alkaline or base soil. If neither colored litmus paper changes, the soil is neutral.

5. Testing for Starches (Demonstration and Activity 4-6)

Materials: Iodine, cornstarch, bread, and a hot dog.

Procedure: Pour a few drops of iodine into a teaspoonful of cornstarch and onto a slice of white bread. Observe both substances for color change.

Discussion: The portions of the cornstarch and bread covered with the iodine become very dark blue or black in color. The chemical reaction between the starch and the iodine brings about the color change.

Many manufacturers of hot dogs use cereals as one of the ingredients mixed with the meat in their products. A high grade hot dog will not have cereal in it. It might make an interesting study for the children to investigate the manufacturers' claim by using the iodine test on a piece of their hot dogs.

6. Testing for Carbon Dioxide (Demonstration or Activity 3-6)

Materials: Lime tablet, jar of water, and a soda straw.

Procedure: Dissolve a lime tablet in a jar of water. Observe the color of the water. Using a soda straw, blow into the water for a minute or so. Observe the color of the water.

Discussion: The water will be clear after the tablet is dissolved in it. As soon as air is blown into the water, it will turn milky white in color. The carbon dioxide from your breath reacts with the lime water and causes this color change. The same reaction will take place if the lime water is exposed to the air in the classroom for a while.

7. Testing for Limestone (Demonstration and Activity)

Materials: Limestone, some dilute hydrochloric acid (HCl), and a medicine dropper.

Procedure: Squeeze a drop of dilute hydrochloric acid from a medicine dropper onto the rock you suspect to be limestone.

Discussion: If the rock is composed of lime, it will effervesce (bubble). Have the children test the concrete sidewalk around the school. What is concrete made of?



VI



Electricity and Magnetism

The studies of electricity and magnetism are placed together under one chapter heading because they are very closely related to each other in many ways.

The demonstrations and activities of this chapter are divided into five sections beginning with Section A, "Learning About Magnets." Here you will find some elementary activities which emphasize the physical characteristics of magnets, the practical application of magnets, and the basic theory of magnetism.

From the principles of magnetism we advance to Section B, "Static Electricity." Here we find activities which the children can use to produce static electricity and observe its effects on various types of materials. In the lower elementary grades knowledge of the theory of static electricity is not necessary in order to draw some conclusions about its operation. These activities include games with static electricity. In the upper elementary grades these same games can be used to explain the basic theory of static electricity, involving the movement of electrons, which produces the attracting and repelling forces of static electricity.

Section C, "Current Electricity," sets the stage for a good understanding of how electricity can be put to useful work in series and parallel circuits. The introduction of special switches will offer a challenge to those students who are highly motivated in the study of electricity.

With a background in static electricity and an understanding of electron flow as demonstrated in static electricity, the students of the upper elementary grades (fourth, fifth, sixth) will find it easier to understand current flow in current electricity and how it is produced in dry cell and wet cell batteries.

Section D brings together the relationship between magnetism and electricity and how one can produce the other. The practical application of this relationship is demonstrated in the construction of generators and motors.

A. LEARNING ABOUT MAGNETS

1. Stop and Go Signs (Activity K-6)

Materials: Two metal disks, two cardboard disks, permanent magnet, red and green paper, paste, and tape.

Procedure: Cut two metal disks from the ends of a tin can. Using paste, cover one disk with red paper and the other with green paper. Cut two cardboard disks the same size as the metal disks. Using paste, cover one cardboard disk with red paper and the other with green paper. Tape a magnet on the wall in a convenient location near the classroom door. Make the two metal disks, one red and one green, available to the children. Instruct the children to place the red disk over the magnet when they leave the room to use the lavatory. The red disk acts like a red traffic signal meaning *stop*, someone has already left the room. Upon returning to the classroom, the children should replace the red disk with the green disk which means *go*. Some morning before the children arrive, substitute the red and green cardboard disks for the red and green metal disks. What happens?

Discussion: When the children attempt to use the cardboard disks, they will immediately realize that they will not be attracted to the magnet. Their first reaction may be to report this fact to their teacher, providing her with the opportunity to introduce a study of those materials which are attracted by magnets and those which are not.

2. Materials Attracted by Magnets and Materials Not Attracted by Magnets (Activity K-6)

Materials: Steel, iron, copper, Canadian five-cent piece, American five-cent piece, glass, plastic, cloth, paper, wood, and a permanent magnet.

Procedure: Attempt to attract the various materials with the permanent magnet. Make a list of materials which are attracted by the magnet and those which are not. Add other materials to those listed above.

Discussion: Materials composed of iron, nickel, or cobalt will be attracted by a magnet. The Canadian five-cent piece has a sufficient quantity of nickel to be attracted by the magnet. The American five-cent piece does not and will not be attracted by the magnet. Steel is an iron alloy, and it is the iron in the steel which becomes magnetized. All the other materials mentioned above will not be attracted by the magnet. Some stainless steels are non-magnetic. It might be interesting to introduce this into the problem to get the children's reaction to it.

3. Attracting and Repelling Magnets (Demonstration and Activity K-6)

Materials: Two permanent magnets with their poles labeled.

Procedure: Move the north pole of one magnet slowly toward the south pole of a second magnet. What happens? Move the north pole of one magnet

slowly toward the north pole of a second magnet. What happens? Repeat this with the south poles of the two magnets.

Discussion: Opposite poles of two magnets are attracted to each other. Like poles of two magnets repel each other.

4. Types of Permanent Magnets and Their Care (Demonstration K-6)

Materials: Various types of permanent magnets: horseshoe, bar, block, "U" shaped, round.

Procedure: Display the above types of magnets as illustrated in Figure 6.1(a). Show how they attract a steel paper clip.

Discussion: These are all permanent magnets made by man. They are called permanent magnets because they hold their magnetism for a long period of time if they are properly cared for.

They should not be dropped or hammered lest they lose their magnetism. Permanent magnets should be kept away from intense heat. They should be stored in a box, either separately or with opposite poles of two magnets together, with an iron or steel "keeper" connecting them as illustrated in Figure 6.1(b). Horseshoe and "U" shaped magnets stored singly should have an iron or steel "keeper" between poles as illustrated in 6.1(b).

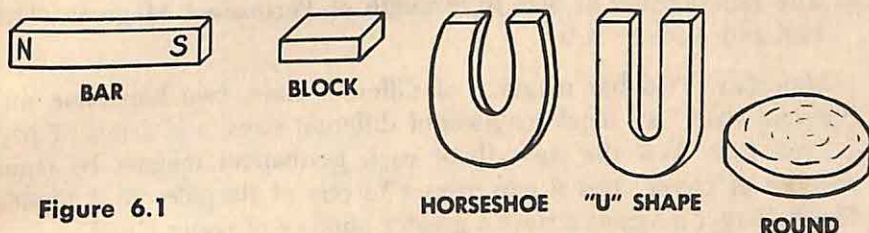
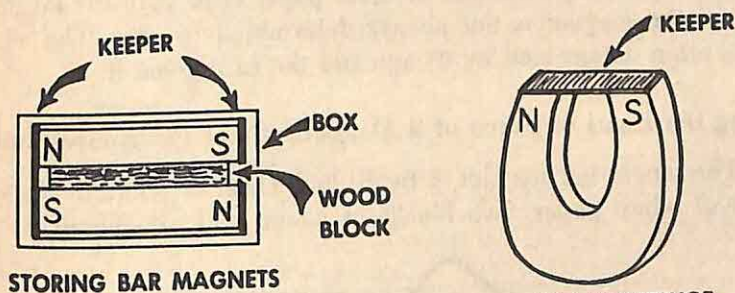


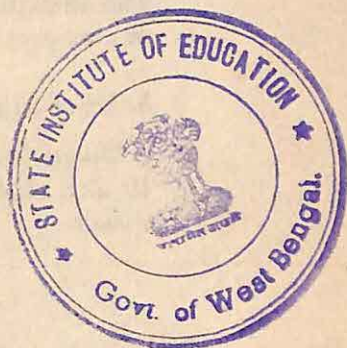
Figure 6.1

(a) TYPES OF PERMANENT MAGNETS



(b) STORING MAGNETS

STORING HORSESHOE
OR "U" MAGNETS



5. Temporary Magnets (Demonstration K-6)

Materials: Permanent magnet, two paper clips.

Procedure: Attract a paper clip to one pole of a permanent magnet. Attract a second paper clip to the end of the first paper clip. What happens to the second paper clip as the magnet is detached from the first paper clip?

Discussion: After the magnet is removed from the first paper clip, the second paper clip falls away. Both paper clips were magnetized temporarily by the permanent magnet. When it was removed, the influence of its magnetism likewise was removed; and the two paper clips separated. The paper clips in this case are considered to be *temporary* magnets. They will keep some of their magnetism for a short time, having a strength great enough to attract small bits of iron filings.

6. Magnetite as a Natural Magnet (Demonstration K-6)

Materials: Piece of magnetite (lodestone) ore, iron filings, and paper clips.

Procedure: Obtain a piece of magnetite iron ore from your high school earth science teacher or from a scientific supply house. Magnetite is a high grade iron ore which has magnetic qualities. Place it next to a steel paper clip or near some iron filings. What happens?

Discussion: The magnetite *may* attract the steel paper clip, depending on the strength of its magnetic field. The iron filings, however, *will* be attracted by even the very weak magnetic field of magnetite.

Magnetite may also be referred to in some parts of the world as *lodestone*.

7. The Relationship of Size to Strength of Permanent Magnets (Demonstration and Activity K-6)

Materials: Two bar magnets of different sizes, two horseshoe magnets of different sizes, two block magnets of different sizes, and a box of paper clips.

Procedure: Test the strength of each permanent magnet by counting the number of paper clips it can attract to one of its poles in a tandem string. Do the larger magnets attract a greater number of paper clips?

Discussion: The children will discover that sometimes the larger magnet will attract a greater number of paper clips, while at other times the smaller magnet will attract the same number or more paper clips than the larger one. The strength of the magnet is not always determined by size. The strength of a magnet is often determined by its age and the care given it.

8. Discovering the Lines of Force of a Magnetic Field (Demonstration 3-6)

Materials: Permanent bar magnet, 8 by 10 inch sheet of window glass, 8 by 10 inch sheet of white paper, two blocks of wood, and iron filings in a salt shaker.

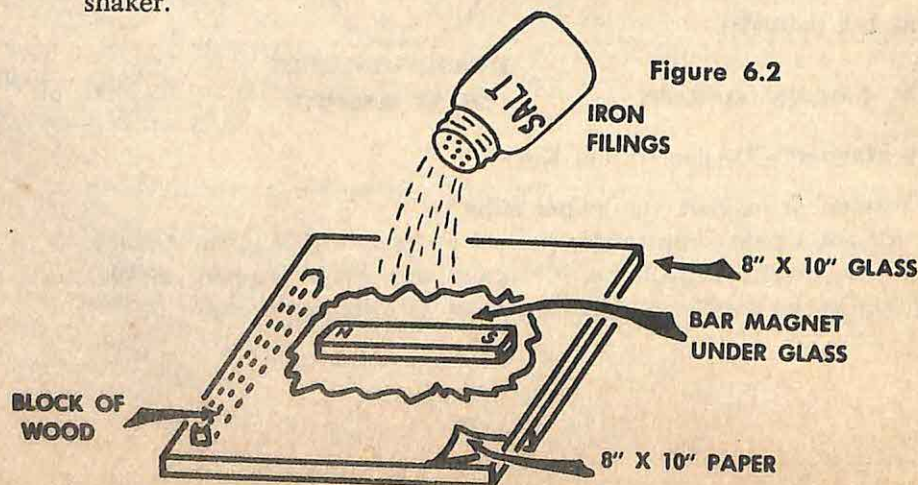


Figure 6.2

Procedure: Set up the above materials as illustrated in Figure 6.2. Sprinkle iron filings on the paper over the area above the bar magnet. Tap the glass gently with your finger or a pencil. What do you observe?

Discussion: The iron filings will reveal the presence of the lines of the magnetic force field of the magnet. Tapping the glass with your finger will help align the iron filings in the magnetic field. The lines of force can now be seen radiating from each pole of the magnet. Have the children trace the lines of force of permanent magnets of other shapes.

9. Tracing the Magnetic Field of Two Attracting Magnets (Demonstration and Activity 3-6)

Materials: Two bar magnets, 8 by 10 inch sheet of window glass, 8 by 10 inch sheet of white paper, two blocks of wood, and iron filings in a salt shaker.

Procedure: Set up the above equipment as illustrated in Figure 6.3(a). Arrange the bar magnets on a table top with opposite poles facing each other at a distance where the attracting forces are not sufficiently strong to overcome the friction between the magnets and table top. Sprinkle iron filings on the paper over the area above the bar magnets. Tap the glass gently with your finger or pencil to align the iron filings in the magnetic field. What pattern do you get?

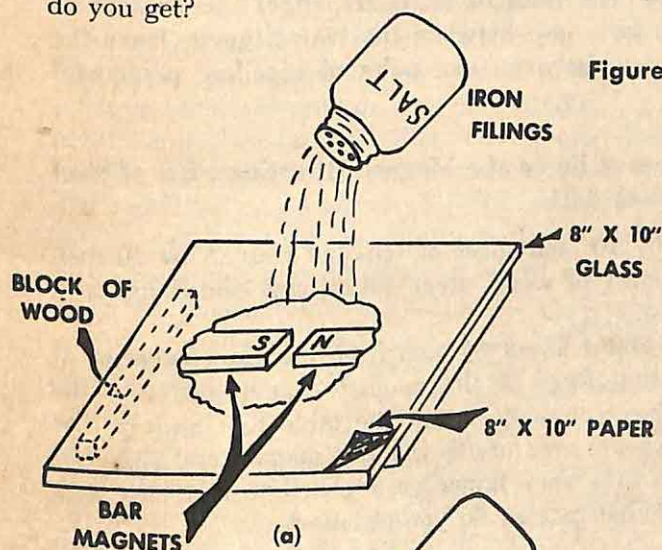


Figure 6.3

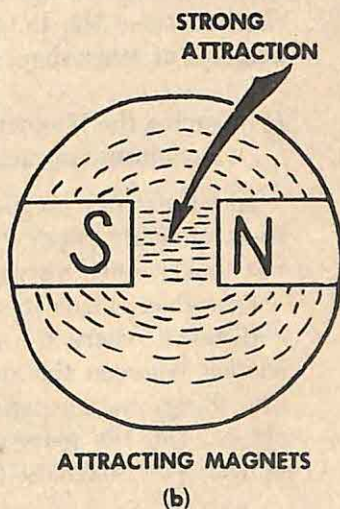
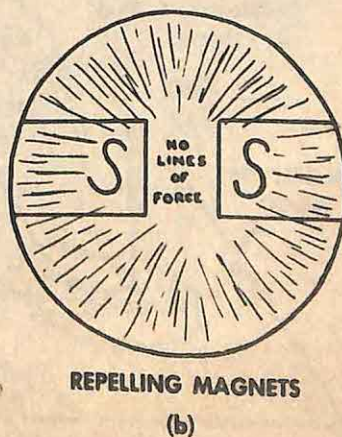
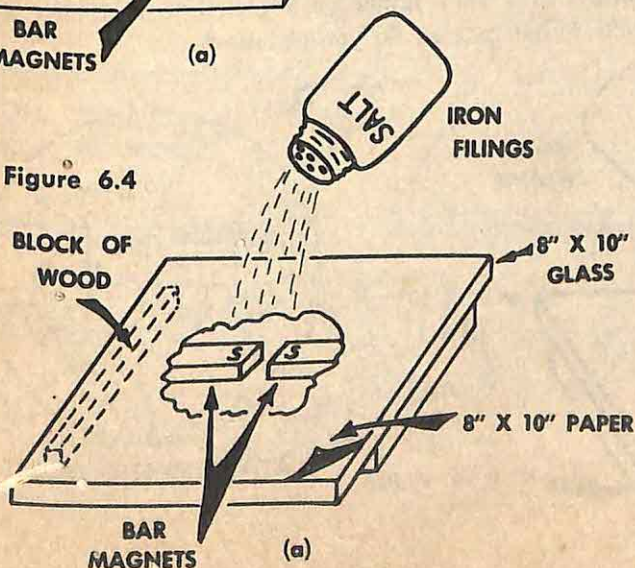


Figure 6.4



Discussion: Figure 6.3(b) illustrates the pattern of the magnetic field between the opposite poles of two magnets. The density of the magnetic lines of force between the two poles of the magnets serves to demonstrate the strong attraction between opposite poles of magnets. Have the children trace the lines of force between the opposite poles of permanent magnets of other shapes.

10. Tracing the Magnetic Field of Two Repelling Magnets (Demonstration and Activity 3-6)

Materials: Two bar magnets, 8 by 10 inch sheet of window glass, 8 by 10 inch sheet of white paper, two blocks of wood, and iron filings in a salt shaker.

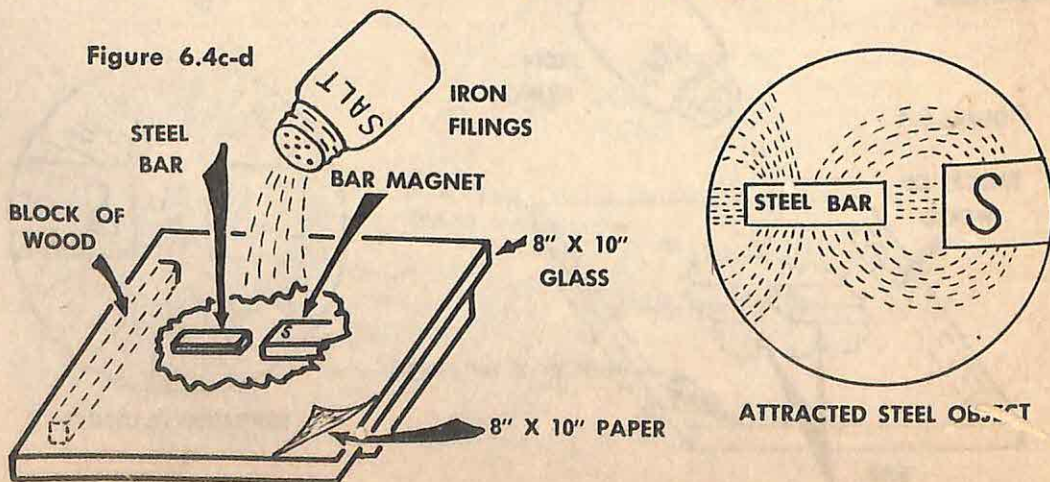
Procedure: Set up the above equipment as illustrated in Figure 6.4(a). Arrange the bar magnets on a table top with like poles facing each other at a distance where the repelling force between the magnets is not sufficiently strong to overcome the friction between the magnets and the table top to repel them further. Sprinkle iron filings on the paper over the area above the bar magnets. Tap the glass gently with your finger or a pencil to align the iron filings in the magnetic field. What pattern do you observe?

Discussion: Figure 6.4(b) illustrates the pattern of the magnetic field between two repelling magnets. The lines of force are either non-existent or very weak. There appears to be a gap between the two magnets. Have the children trace the lines of force between like poles of repelling permanent magnets of other shapes.

11. Tracing the Magnetic Lines of Force of a Magnet Attracting a Bar of Steel (Demonstration and Activity 3-6)

Materials: Bar magnet, 8 by 10 inch sheet of window glass, 8 by 10 inch sheet of white paper, two blocks of wood, steel object, and iron filings in a salt shaker. (See Figure 6.4a.)

Procedure: Place the steel object about $\frac{1}{2}$ inch from the bar magnet or at a distance where the attracting force of the magnet cannot overcome the friction between the steel object or magnet and the table top. Sprinkle the iron filings on the paper over the area above the bar magnet and the steel object. Tap the glass gently with your finger or a pencil to align the iron filings in the magnetic field. What pattern do you observe?



Discussion: Figure 6.4(d) illustrates the pattern of the magnetic field of the bar magnet and the steel object. If this picture is compared with Figure 6.3(b), a direct relationship between the two force fields will be perceived. The pattern is identical. The magnetic field of the magnet magnetizes the steel bar which immediately takes on the characteristics of a magnet with a north and south pole.

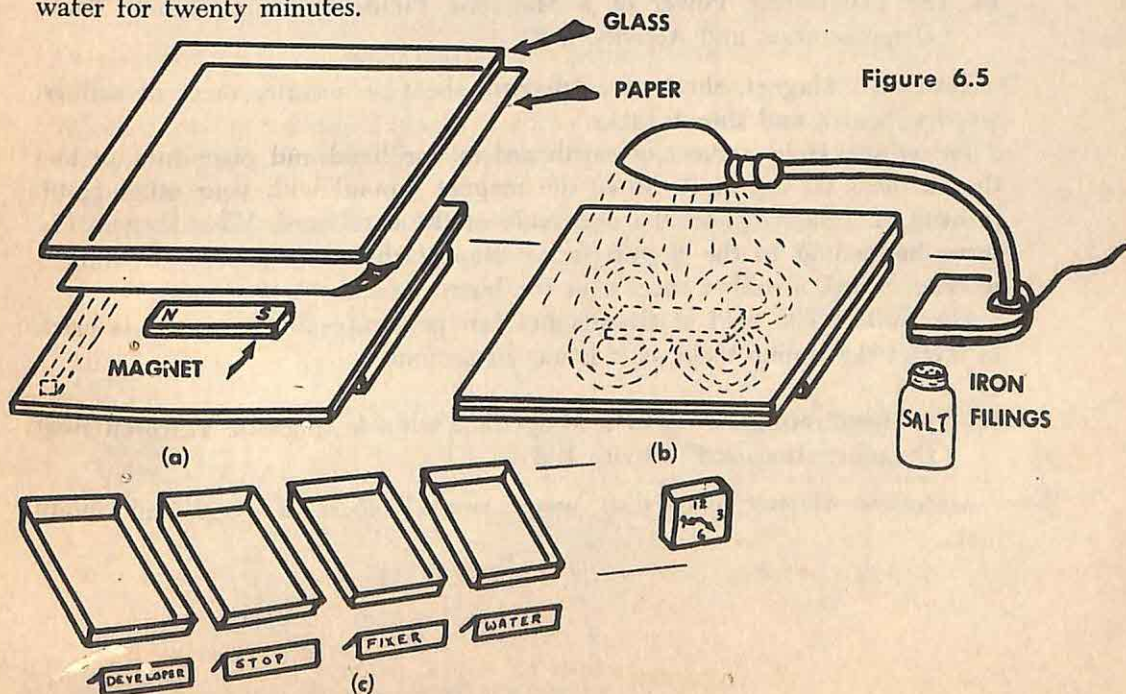
12. Photogram of a Magnetic Field (Demonstration and Activity 4-6)

Materials: Photographic paper in 8 by 10 inch sheets (Kodak Velite), desk lamp (100 watt bulb), four shallow pans, Kodak Tri-Chem Pack for developing, watch, two 8 by 10 inch sheets of window glass, iron filings in a salt shaker and magnets.

Procedure: Arrange the magnet, glass, and photo paper in a sandwich as illustrated in Figure 6.5(a). The Velite photographic paper is not sensitive to normal classroom light. It is, however, sensitive to sunlight. Pull the shades and switch off all the lights in your classroom as a precautionary measure before exposing the paper. Even with your room darkened, more than adequate light will be available for working.

Sprinkle iron filings on the paper over the area above the magnet. Tap the glass gently with your finger or a pencil to align the iron filings in the magnetic field. Place a desk lamp over the magnetic field at a height of about 12 inches as illustrated in Figure 6.5(b). Expose the Velite paper to the light for about 5 seconds; then remove it from between the two panes of glass.

Set up the developing pans as illustrated in Figure 6.5(c). Mix the chemicals in the Tri-pack as directed. Place the exposed Velite paper into the *developing solution* and agitate for one to two minutes or until the exposed areas are black and the unexposed areas (those which were under the iron filings) are white. Next, place it in the *stop bath* for about 20 seconds. From the stop bath place the paper into the *fixer* for about ten minutes; then wash the print in water for twenty minutes.



Discussion: A photogram of the magnetic field has produced a permanent record for future reference.

This activity could easily initiate a study of photography, light, or creative photography using magnets, iron filings, paper cutouts, or other objects to form artistic patterns.

13. Making an Electro-Magnet (Activity 3-6)

Materials: Three foot length of bell or annunciator wire, large steel nail, a $1\frac{1}{2}$ volt dry cell, and some steel paper clips.

Procedure: Coil ten turns of wire around a steel nail or bolt and connect the ends of the wire to a $1\frac{1}{2}$ volt dry cell as illustrated in Figure 6.6. How many steel paper clips can you pick up in tandem? Increase the number of windings to 20, 30, 40, etc. How many steel paper clips can you pick up each time in tandem? What happens to the strength of the electro-magnet as the number of windings is increased? Keep a record of your observations.

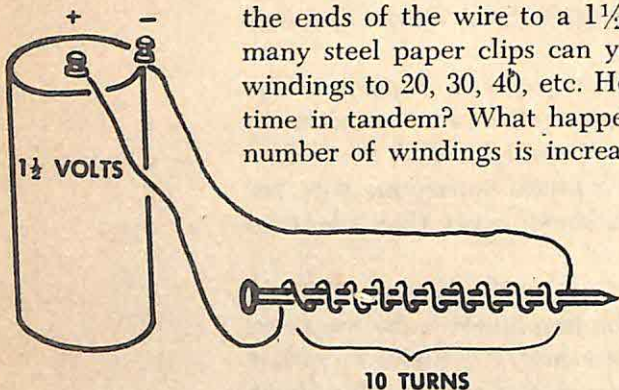


Figure 6.6

Discussion: The wire coiled around the steel nail induces a magnetic field around the nail. As the number of turns of wire is increased, the strength of the magnetic field is also increased so that more paper clips can be held in tandem by the electro-magnet. For this experiment to succeed, the length of the wire must remain constant for all numbers of windings. In what other ways can the strength of an electro-magnet be increased?

14. The Penetrating Power of a Magnetic Field: Dancing Thumb Tacks (Demonstration and Activity K-6)

Materials: Magnet, sheet of cardboard, sheet of acetate, sheet of rubber, wooden board, and thumb tacks.

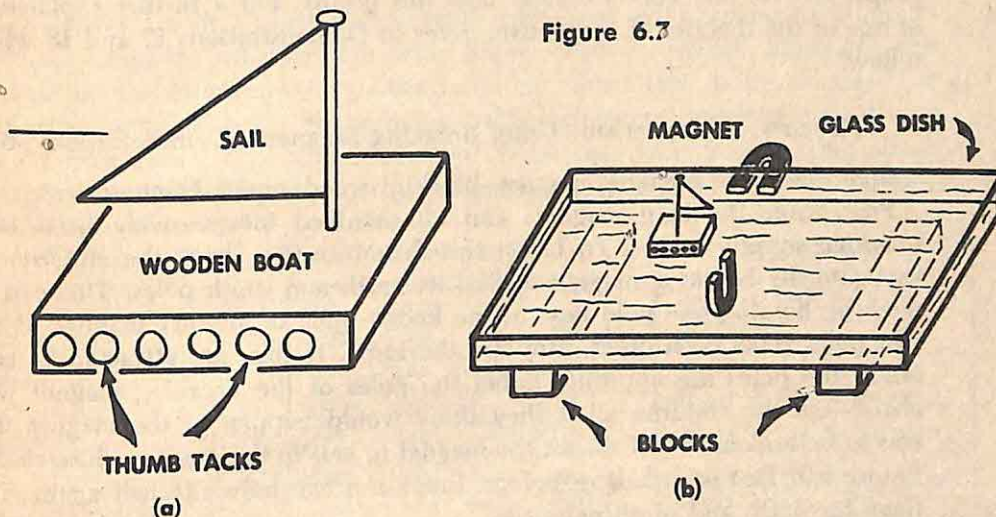
Procedure: Hold a sheet of cardboard in one hand and place four or five thumb tacks on top of it. Move the magnet around with your other hand, pressing it lightly against the underside of the cardboard. What do you observe happening to the thumb tacks? Repeat the same procedure using a wooden board, a rubber sheet over the board, and sheet of acetate.

Discussion: The field of the magnet can penetrate all the materials used, to attract the thumb tacks as it is moved around.

15. The Penetrating Power of a Magnetic Field: A Magnetic Powered Boat (Demonstration and Activity K-6)

Materials: Magnet, glass dish, water, several blocks of wood, and thumb tacks.

Procedure: Insert several thumb tacks in the sides, ends, and bottom of a small block of wood as illustrated in Figure 6.7(a). Float the block of wood in a dish of water. Set the dish on two bricks or blocks of wood as illustrated in Figure 6.7(b). Hold a magnet under the dish in close proximity to the floating block of wood. What happens? Move the magnet around slowly under the dish. What happens? Move the magnet around the edge of the glass dish in close proximity to the floating block of wood. What happens?



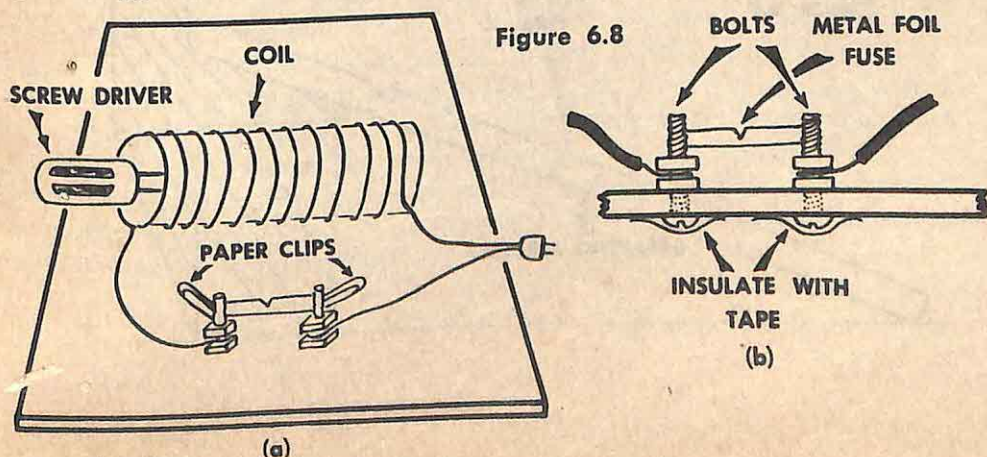
Discussion: The magnetic field of the magnet will penetrate the glass dish and water and will attract the steel thumb tacks in the block of wood, moving it toward the magnet.

16. Making a Magnetizer (Demonstration 4-6)

Materials: Insulated electrical wire, cardboard cylinder, two bolts with four nuts, sheet of corrugated cardboard or a $\frac{1}{4}$ inch plywood board, plug, tin foil gum wrapper, two paper clips, and a piece of steel or a screwdriver.

Procedure: Coil insulated wire several hundred times around a cardboard cylinder, leaving a one foot length of wire on each end of the coil as illustrated in Figure 6.8(a). Connect these wires to the bolts and plug as illustrated in Figure 6.8(b).

To operate this magnetizer, use paper clips to fasten a strip of tin foil from a gum wrapper to the two bolts as shown in Figure 6.8(a). Cut a deep notch



in the tin foil. This will perform the function of a fuse. Insert the steel rod, nail, bolt, or screwdriver you wish to magnetize into the cylinder. Now *and only now* insert the plug into the wall socket. After the fuse has blown, *pull the plug out of the socket* and then remove the steel object and test it for magnetism.

Discussion: The sudden surge of electrical current in the coil affects the arrangement of the molecules of steel, causing the object to take on magnetic properties. No one knows exactly how this occurs. For a further explanation of one of the theories of magnetism, refer to Demonstrations 17 and 18 which follow.

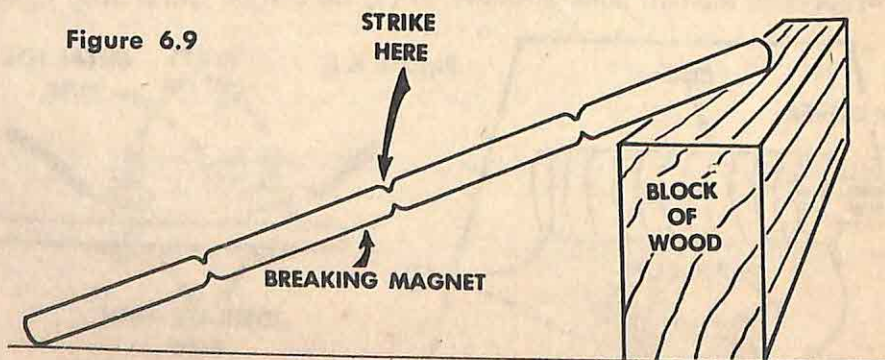
17. A Theory of Magnetism: Using Breaking Magnets (Demonstration 4-6)

Materials: One breaking magnet, block of wood, and a hammer.

Procedure: Breaking magnets can be obtained inexpensively from most scientific supply houses. To begin this demonstration, have the children investigate the breaking magnet to find its north and south poles. This can be done by holding one pole next to the known pole of another magnet. If the two poles repel each other, they are the same. If they are attracted to each other, the poles are opposite. Label the poles of the breaking magnet with chalk. Ask the children what they think would happen to the magnet if it was to be broken in half. Break the magnet in half in the manner illustrated in Figure 6.9. Test each half as before. Break the two halves in half again. Test them for north and south poles too.

Discussion: As the breaking magnet is broken into smaller parts, each smaller part becomes an individual magnet with a north and a south pole. The problem to propose to the children at this point is: what would happen to each smaller piece of magnet if we continued to break it up? Each smaller piece would become an individual magnet.

How small could we break up this magnet? If we broke it up into individual atoms, would each atom have a north and south pole? We are not sure that it would, but it is reasonable to believe that it might. We have deduced, then, that a magnet is made up of atoms each of which, when found alone, may have the properties of a magnet. We have deduced this theory, however, *not proved it*. We might also deduce that, as we add these same atoms together, we make a larger and larger magnet. The next demonstration carries this theory one step further.



18. A Theory of Magnetism (Demonstration 4-6)

Materials: Two large illustrations of the arrangement of atoms in an iron bar.

Procedure: Display to the children a large copy of Figure 6.10(a). This diagram shows the arrangement of atoms in an iron bar which is not magnetized. (The atoms are not drawn to scale.) The atoms appear as tiny magnets, each with a north and a south pole. The arrangement of atoms is random. Compare this diagram with Figure 6.10(b), which illustrates the arrangement of atoms in a magnetized iron bar. The atoms in this diagram are uniformly arranged with all the north poles facing one direction and all the south poles facing the other direction. What can you deduce from these diagrams about the relationship of magnetism to the arrangement of atoms in an iron bar?

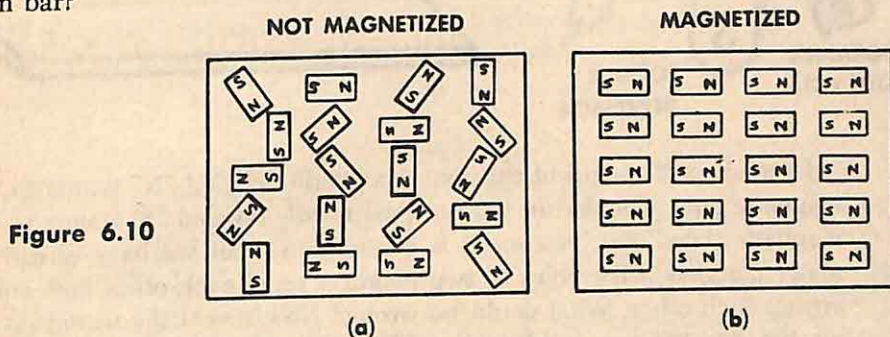


Figure 6.10

Discussion: Two things can be deduced. The arrangement of atoms in an iron bar makes the difference between a magnetized iron bar and a non-magnetized iron bar. In an iron bar magnet the north poles of the atoms are almost all facing in one direction to create the north pole of the magnet, while the south poles of the atoms facing the other direction create the south pole of the magnet. Atoms in an iron bar which are lined up add to the magnetism of the bar. If the atoms are randomly arranged, then their effect simply averages to zero.

19. The Magnetic Field of the Earth (Demonstration 4-6)

Materials: Rubber ball 4 to 6 inches in diameter, wooden tongue depressor, bar magnet, two paper flags, tape, and a compass.

Procedure: Tape a bar magnet to a wooden tongue depressor and insert in a rubber ball as illustrated in Figure 6.11. Note that the south pole of the magnet is at the north magnetic pole of the ball (earth), and the north pole of the magnet is at the south magnetic pole of the earth. Do not let the children know this fact at this time. The flags represent the north and south *geographic poles* of the earth. Hold the compass in your hand and bring it near the north magnetic pole. Which end of the compass needle points toward the north magnetic pole, the "N" or the "S"? Which end of the compass needle points toward the south magnetic pole?

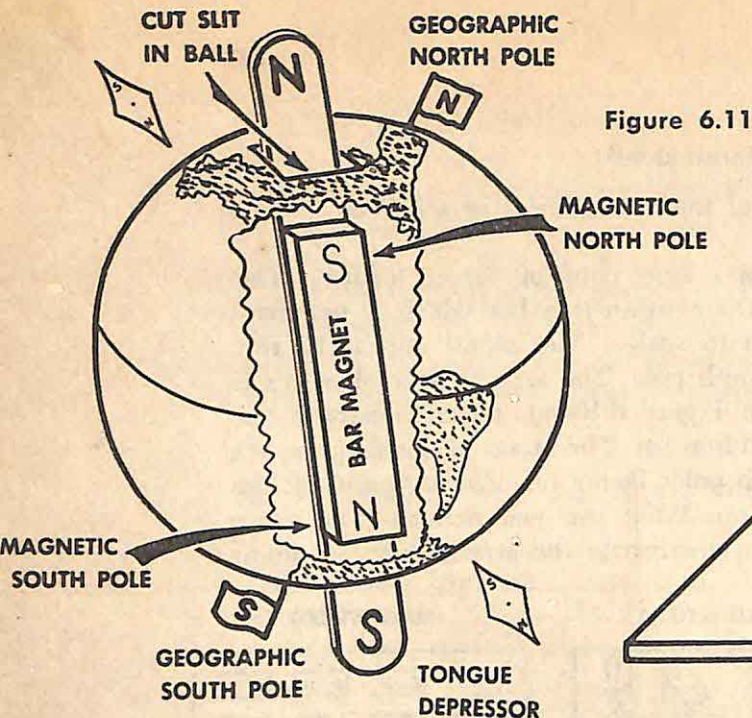


Figure 6.11

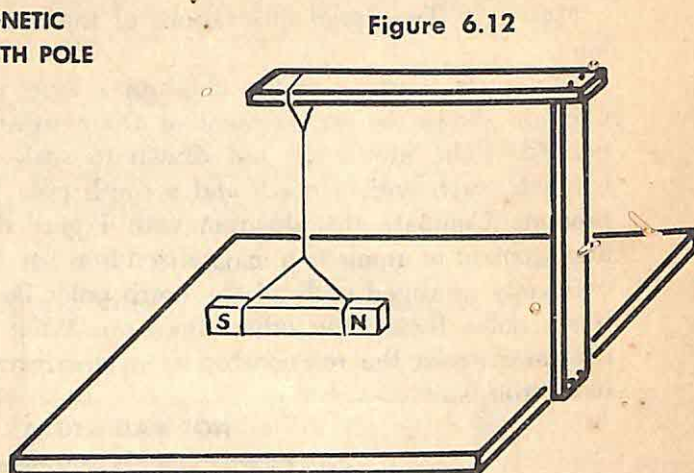


Figure 6.12

Discussion: The end of the compass needle labeled "N" points to the north magnetic pole. The end of the compass needle labeled "S" points to the south magnetic pole. This, of course, is contrary to what we have already learned about magnets. Like poles of two magnets repel each other and unlike poles attract each other. What could be wrong? Now reveal the names on the label on the bar magnet inside the rubber ball (earth). One of two things is wrong in this situation: either the north magnetic pole is really a south magnetic pole or the compass needle labeled "N" is the south pole of a magnet. The answer can be found in history books. When man first used a compass, he called the end of the needle that pointed north the *north-seeking needle* and gave it the label "N" or north. Thus the north-seeking pole of the compass is actually a south pole of a magnet which is attracted to the earth's north magnetic pole. Could it be that the earth's magnetic north pole is really a south magnetic pole and the compass needle marked "N" is really a north magnetic pole? No one really knows. To change the designation of the earth's pole now would be extremely confusing, as you can well imagine.

It should also be noted that the geographic poles are different from the magnetic poles in physical location. The approximate center of the north magnetic pole is located about 1,200 miles from the geographic pole, in other words in Canada, and the magnetic south pole is located about the same distance from the south geographic pole.

20. Making a Compass From a Free Swinging Magnet (Demonstration 3-6)

Materials: Bar magnet, string, tape, and a wooden bracket.

Procedure: Set up the above equipment as illustrated in Figure 6.12. Place a piece of tape over each pole label on the bar magnet. Allow the magnet to

swing freely. After it stops swinging, remove the labels. Which end of the magnet points north and which end points south?

Discussion: The north pole of the magnet will point toward the magnetic north pole of the earth and the south pole toward the south magnetic pole. The poles of newly magnetized iron or steel bars can be determined in this manner. A free swinging magnet can thus be used as a compass.

21. Making a Floating Needle Compass (Activity 4-6)

Materials: Peanut butter jar with screw on lid, sewing needle, cork disk, magnet, water, and a crayon.

Procedure: Hold the needle in your hand between your thumb and forefinger and magnetize it by stroking it with a permanent magnet in one direction only as illustrated in Figure 6.13(a). Using a knife, remove the cork disk from a pop bottle cap and glue the magnetized needle to it as illustrated in Figure 6.13(b). Half-fill the peanut butter jar with water and float the cork and needle on the surface of the water as illustrated in Figure 6.13(c). Label the jar with the four cardinal compass directions as shown.

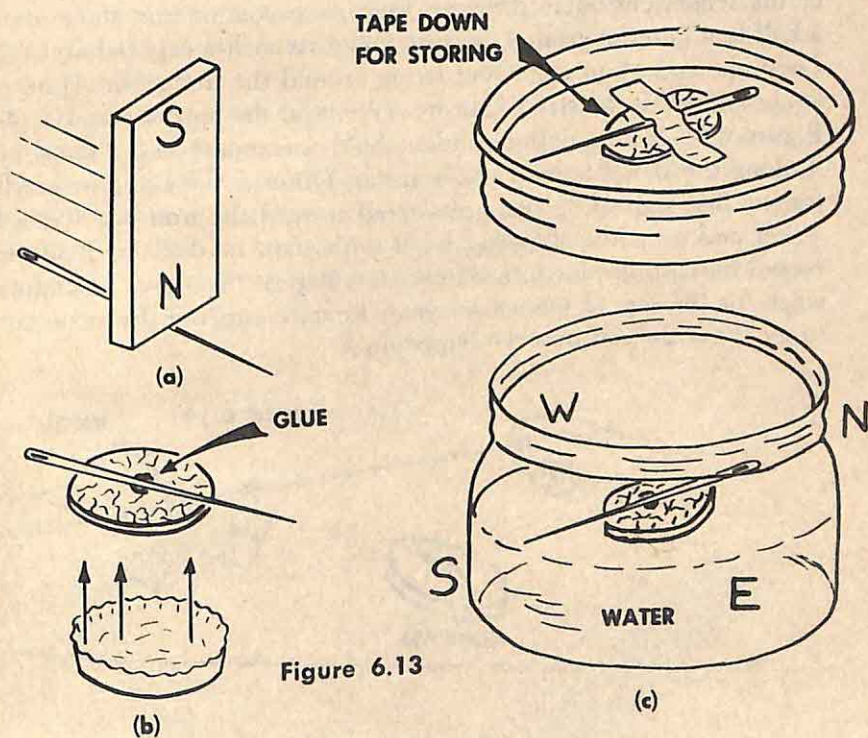


Figure 6.13

Discussion: The needle is a floating magnet which will orient itself with magnetic north and south as a compass should. This device makes a good portable compass which can be taken on hikes and field trips. The needle and cork float can be stored during transit by taping it to the underside of the jar lid. This will prevent damage to the cork float.

22. The Magnetizing Power of the Earth (Activity 4-6)

Materials: Compass.

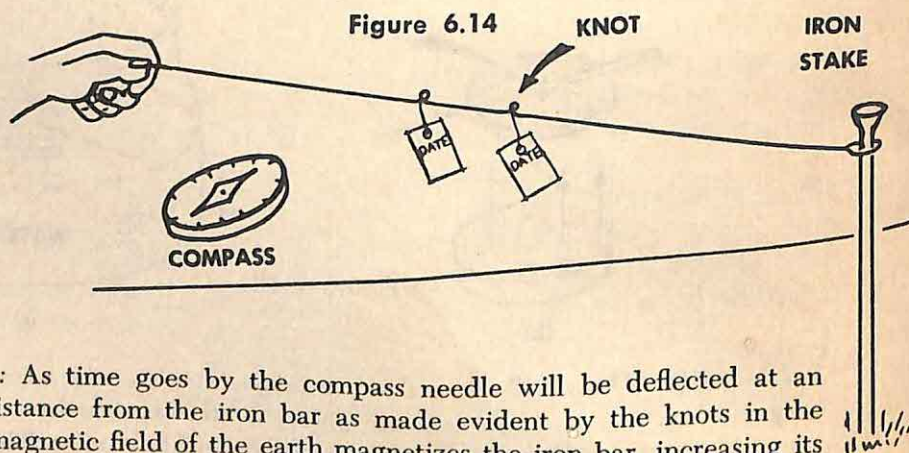
Procedure: Locate several iron or steel fence posts which have been in the ground for several years. Bring a compass near each fence post. What happens to the compass?

Discussion: The compass needle will be attracted to the iron or steel post and deviate from its normal north-south alignment. The iron or steel post has been magnetized by the earth's magnetic field. Surveyors use a compass-like device to locate iron bench marks and iron water pipes under the ground. See if your class can find the cast iron water main that leads into their school.

23. Making a Quantitative Study of the Effects of the Earth's Magnetic Field on an Iron Bar (Activity 4-6)

Materials: Iron bar 3 feet in length, string, a compass, and some shipping labels.

Procedure: Early in the school year have a few of your stronger boy students or the school custodian drive an iron fence post or iron stake about two and a half feet into the ground, leaving about six inches exposed above the ground. Loop one end of an eight foot string around the iron stake. Have one of your students stretch the string taut by pulling on the opposite end as illustrated in Figure 6.14. Have another student hold a compass in his hand and advance it along the string toward the iron bar. Observe the compass needle carefully for the first sign of its being deflected toward the iron bar. Tie a knot in the string and attach a shipping label with date marked on it at this point to record the distance for future reference. Repeat the above procedure once each week for the rest of the school year. Be sure you use the same compass each time. What do you observe happening?



Discussion: As time goes by the compass needle will be deflected at an increasing distance from the iron bar as made evident by the knots in the string. The magnetic field of the earth magnetizes the iron bar, increasing its magnetic attraction for the compass needle as time passes. There will be a limit to its magnetic attraction as time passes.

B. STATIC ELECTRICITY

1. Producing Static Electricity With Pencil and Paper (Demonstration and Activity K-6)

Materials: Sheet of notebook paper and pencil.

Procedure: Place a sheet of notebook paper flat on a desk and rub the flat surface of a pencil back and forth across it for several seconds. Lift up on one corner of the sheet of paper and release it. What happens?

Discussion: The paper has a tendency to adhere to the desk top. Static electricity was created by the friction between the pencil and paper. Try the same activity with the paper lying flat against the chalkboard.

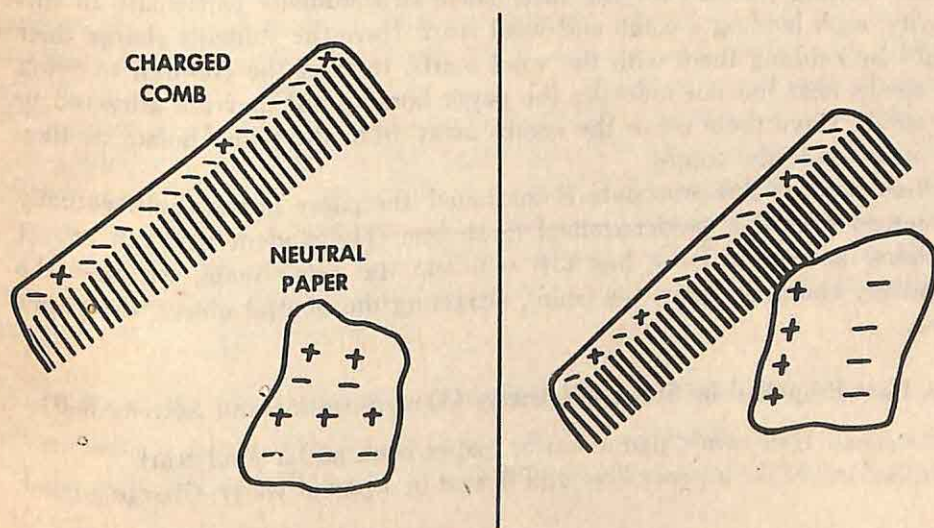
2. Producing Static Electricity with a Haircomb (Demonstration and Activity K-6)

Materials: Hair comb, small bits of paper, and a head of hair.

Procedure: Run a plastic or hard rubber comb through your hair several times and then place it in close proximity to several small bits of paper. What happens to the paper?

Discussion: The small pieces of paper are attracted to the comb as illustrated in Figure 6.15(b). The hair gives up electrons to the comb, giving it a negative charge as in Figure 6.15(a). As the *negatively charged* comb is brought closer to the *neutral* (equal number of positive and negative charges) paper, the negative charges in the paper are repelled to the opposite side, and the positive charges in the paper are attracted to the negatively charged comb as illustrated in Figure 6.15(b). Opposite charges attract and like charges repel.

Figure 6.15



3. Producing Static Electricity with a Rubber Balloon (Demonstration and Activity K-6)

Materials: Rubber balloon, small bits of paper, and a wool or silk scarf.

Procedure: Rub the balloon with a wool or silk scarf. Bring the balloon near several bits of paper. What happens to the bits of paper?

Discussion: Wool or silk tend to give up electrons to the rubber balloon, which gives it a negative charge. The *negatively* charged balloon will attract the *neutral paper* in the same manner as did the negatively charged comb in the previous demonstration and activity.

4. Dancing Paper Dolls (Demonstration and Activity K-6)

Materials: Aluminum cake tin, tissue paper, 8 by 10 inch sheet of window glass, and a wool scarf or a piece of fur.

Procedure: Cut out two or three tissue paper dolls a little shorter than the depth of the aluminum cake tin. Place the paper dolls in the cake tin and cover it with an 8 by 10 inch sheet of window glass. Rub the glass vigorously with a wool scarf or piece of fur and observe the paper dolls.

Discussion: The paper dolls will jump up and down as the intensity of the charge on the glass changes. The glass becomes negatively charged when rubbed with the wool scarf or fur. The negative charges of the neutral paper dolls are repelled to the other end of the paper, leaving behind the positive charges which are attracted to the negatively charged glass. Opposite charges attract.

5. Paper Horses Made to Race (Demonstration and Activity)

Materials: Two hair combs, thin tracing paper, and a wool or silk scarf.

Procedure: Cut out two paper horses from thin tracing paper. Place the horses side by side about one foot apart on a smooth-surfaced table. This will be the starting position for the race. Have two students participate in this activity, each holding a comb and wool scarf. Have the students charge their combs by rubbing them with the wool scarfs. Instruct the children to bring the combs near but not touching the paper horses until they are attracted to the comb. Have them move the combs away from the paper horses as they are attracted to the combs.

Discussion: As this procedure is continued, the paper horses can eventually be moved toward a predetermined finish line. The student that can attract his horse across the finish line first will win the race. Again, we have the negatively charged object, the comb, attracting the neutral object, the paper horse.

6. A Boat Propelled by Static Electricity (Demonstration and Activity K-6)

Materials: Hair comb, pan of water, paper boat, and a wool scarf.

Procedure: Make a paper boat and float it in a pan of water. Charge a comb

by rubbing it with a wool scarf. Place the comb near but not touching the paper boat. What happens to the boat?

Discussion: Like the paper horses, the paper boat is attracted by the negatively charged comb and is propelled across the pan of water.

7. Theory of Attracting and Repelling Objects (Demonstration 4-6)

Materials: Sheet of plastic, rubber balloon, wool scarf, and silk scarf.

Procedure: Rub a plastic sheet with a wool scarf or a silk scarf. Rub an inflated balloon with a wool or silk scarf. Hold the plastic sheet in one hand and the wool scarf in the other hand. Bring them together slowly. Bring the plastic sheet and the silk scarf together. Bring the inflated rubber balloon together with the wool scarf and the silk scarf. What will happen when the rubber balloon and the plastic sheet are brought together? What will happen when the wool scarf and the silk scarf are brought together?

UNLIKE CHARGES ATTRACT

(a)

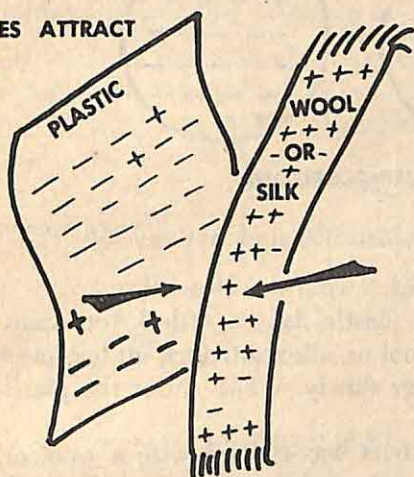
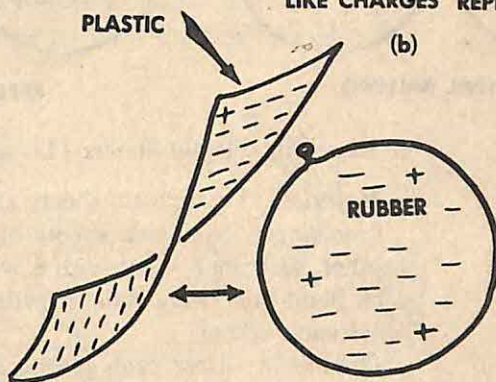


Figure 6.16

LIKE CHARGES REPEL

(b)



Discussion: When the plastic sheet and rubber balloon are rubbed with the wool or silk, they become negatively charged. The wool and silk have a tendency to give up their electrons easily, whereas the plastic and rubber have a "hunger" for electrons. The wool and silk become positively charged as they lose electrons to the plastic and rubber. The negatively charged plastic and rubber are attracted to the positively charged wool and silk when brought near them as illustrated in Figures 6.16(a). Here we see *opposite charges attracting*. The contrary occurs when materials of like charges come together. The negatively charged plastic and the rubber balloon repel each other as do the positively charged silk and wool. *Like charges repel* each other as illustrated in Figure 6.16(b).

8. Theory of Repelling Balloons (Demonstration and Activity 4-6)

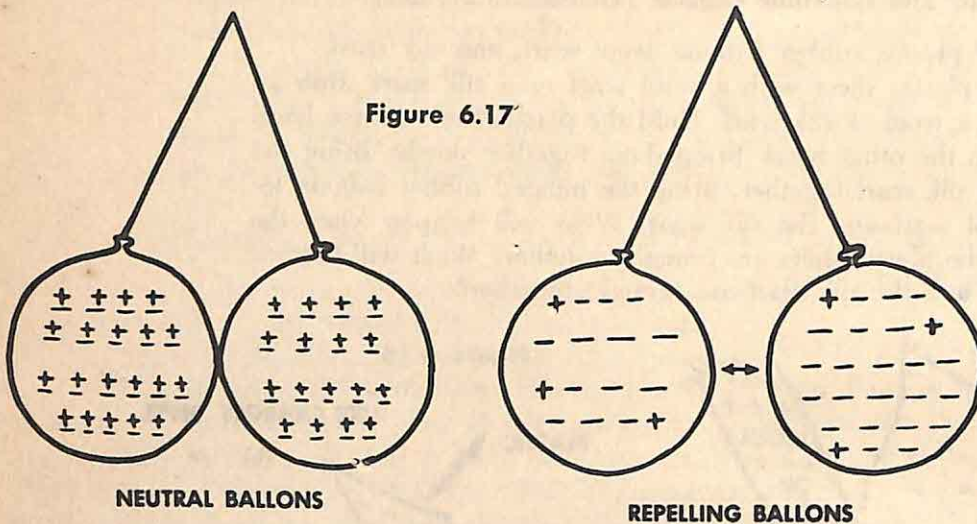
Materials: Two rubber balloons, string, and a wool or silk scarf.

Procedure: Inflate two rubber balloons and suspend them from separate

strings so that they will touch each other. Rub each balloon with a wool or silk scarf. What causes the balloons to separate?

Discussion: After each balloon was rubbed with a wool or silk scarf, it became negatively charged, causing the two balloons to repel each other as illustrated in Figure 6.17.

Figure 6.17



9. Repelling Plastic Sheets (Demonstration and Activity 4-6)

Materials: Two plastic sheets and a wool or silk scarf.

Procedure: Place two sheets of plastic flat on a desk top apart from one another. Rub each sheet with a wool or silk scarf. Pick up one plastic sheet in each hand and bring them together slowly. What causes the plastic sheets to repel each other?

Discussion: After each plastic sheet was rubbed with a wool or silk scarf, they became negatively charged and caused the two to repel each other as illustrated in Figure 6.18.

Figure 6.18

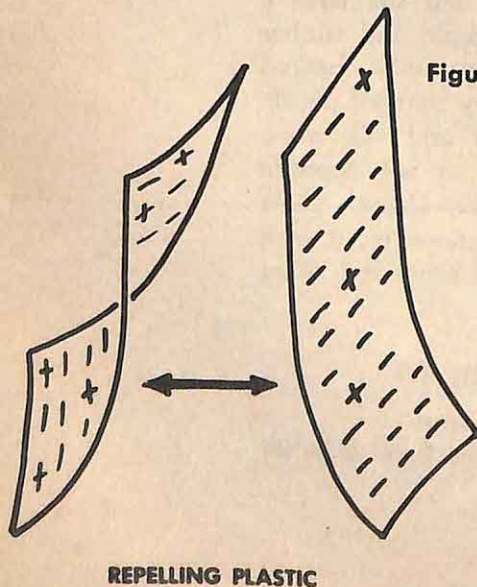
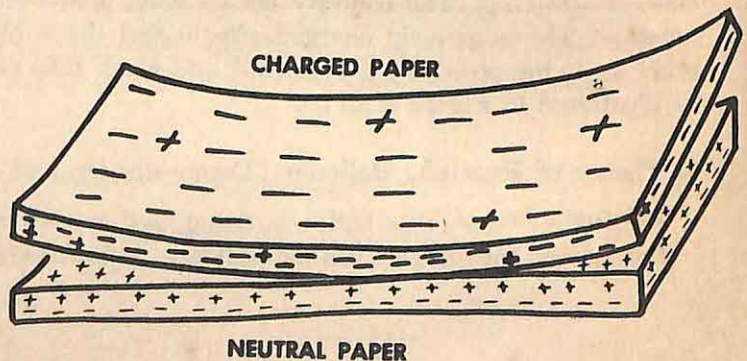


Figure 6.19



10. Attracting a Neutral Material (Demonstration 4-6)

Materials: Two sheets of notebook paper and a wool scarf.

Procedure: Demonstrate to the children that two sheets of notebook paper neither attract nor repel each other. Rub one sheet of paper with a wool scarf to charge it negatively. The wool scarf gives up many of its electrons to the paper, charging it negatively. Pick up the negatively charged paper and bring it near the uncharged sheet of paper. What causes the two sheets of paper to come together?

Discussion: As the negatively charged paper is brought near the neutral paper, the negative charges in the neutral paper are repelled to the opposite side, leaving the positive charges behind. These positive charges are attracted to the negatively charged paper; thus the neutral paper is attracted to the negatively charged paper as illustrated in Figure 6.19.

11. Making an Electroscope (Activity 4-6)

Materials: Narrow mouthed glass jar or bottle, cork, length of copper wire, aluminum foil gum wrapper or tissue paper, plastic sheet, and a wool scarf.

Procedure: Construct a simple electroscope as illustrated in Figure 6.20.

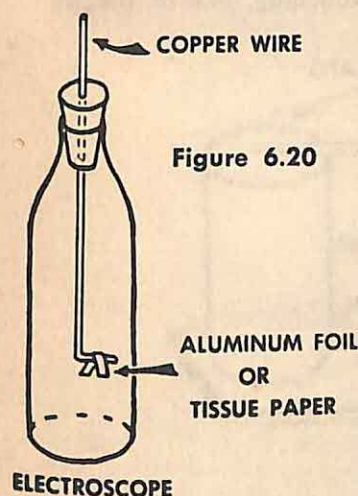


Figure 6.20

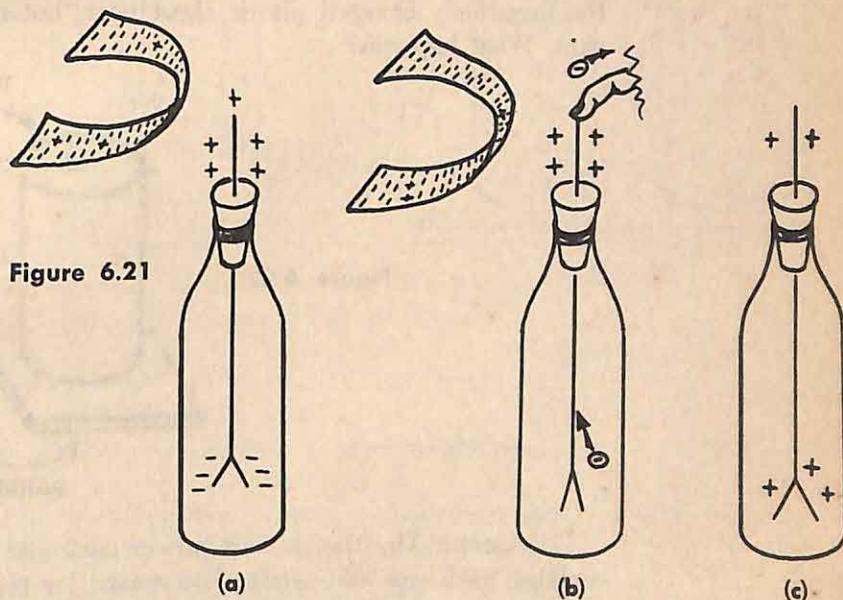


Figure 6.21

An electroscope is a device which enables us to learn the type of static charge an object has. In order to determine the charge on an object, the electroscope must be given a known charge. It is customary to give the electroscope a positive charge as demonstrated in the three steps in Figure 6.21.

Bring a negatively charged plastic sheet near to the protruding copper wire but not touching it. The electrons in the copper wire are repelled into the aluminum or tissue paper leaves as illustrated in Figure 6.21(a).

Touch the end of the wire with your finger. The electrons which were repelled to the leaves before will flow into your hand and body (ground). The leaves will collapse, as shown in Figure 6.21(b), and the end of the wire will remain positively charged. Remove your finger first, then the negatively charged plastic. This gives the electroscope a positive charge with the leaves diverged.

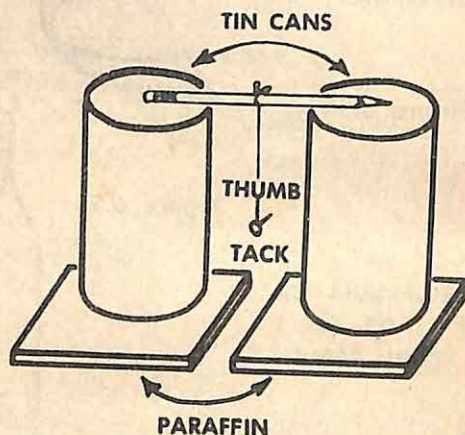
Discussion: With your electroscope positively charged, it is ready for use. If a negatively charged material is placed near to, but not touching, the end of the wire, which way will the leaves move? Together! If a positively charged material is placed near the electroscope, which way will the leaves move? Further apart! Investigate the charge of wool, silk, glass, rubber, plastic, paper, and nylon when rubbed with each other.

12. Electrons in Motion (Demonstration and Activity 4-6)

Materials: Two tin cans, two paraffin blocks, thumb tack, sewing thread, plastic sheet, and a wool scarf.

Procedure: Set up the above equipment as illustrated in Figure 6.22. Place the tin cans about $\frac{1}{2}$ inch apart, bridging them with a pencil as shown. Suspend a thumb tack from a pencil at the end of a thread between the cans. Rub the plastic sheet with the wool scarf to give it a negative charge. Bring the negatively charged plastic sheet near, but not touching, one of the tin cans. What happens?

Figure 6.22



Discussion: The thumb tack moves back and forth between the two cans striking each can alternately. The reason for this movement is demonstrated in three steps in Figure 6.23.

The negatively charged plastic sheet repels the electrons in the near can as illustrated in Figure 6.23(a).

The neutral thumb tack is attracted to the negatively charged side of the can as illustrated in Figure 6.23(b).

The thumb tack picks up electrons from the can, becomes negatively charged, and is repelled to the other can. Here it discharges the electrons it has picked up as illustrated in Figure 6.23(c).

The thumb tack again becomes neutral and swings back to the first can where it picks up more electrons, is repelled, and again discharges its electrons to the second can. Eventually the second can will have more electrons than the first can as illustrated in Figure 6.23(d).

If the plastic sheet was taken away, what do you think would happen? Yes, the electrons would be ferried back to the first can again by the thumb tack, and both cans will again have a neutral charge. Try it and see! Electrons in motion constitute electric current.

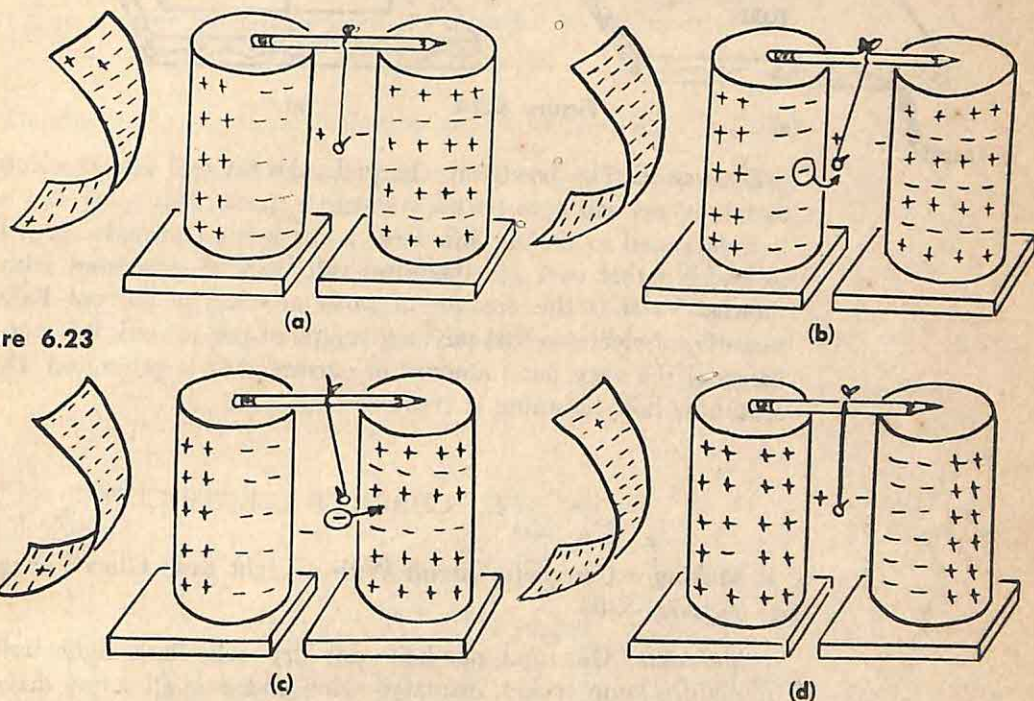


Figure 6.23

13. Making an Electrophorus (Activity 4-6)

Materials: Rubber inner tube, cake or pie tin, two rubber bands, sheet of plastic, an 8 by 10 inch wooden board, and a wool scarf.

An *electrophorus* is one of the simplest devices used to produce electricity by induction.

Procedure: Stretch over a board a sheet of rubber cut from an inner tube and tack it in place. Cover the rubber sheet with a plastic sheet but *do not* tack it. Stretch two rubber bands around a cake tin as illustrated in Figure 6.24(a). To charge your electrophorus, rub the plastic sheet with the wool scarf. Place the cake tin on the plastic sheet as shown in Figure 6.24(b). Touch the bottom of the cake tin with your finger. The electrons of the cake tin, which were repelled to the inside of the pan, flow into your hand leaving the cake tin positively charged. Now you are ready to use your charged electrophorus. Pick up the cake tin by the rubber bands and bring it close to a metal object such as a radiator or faucet. What happens? Charge it again and have a friend bring his finger near the cake tin.

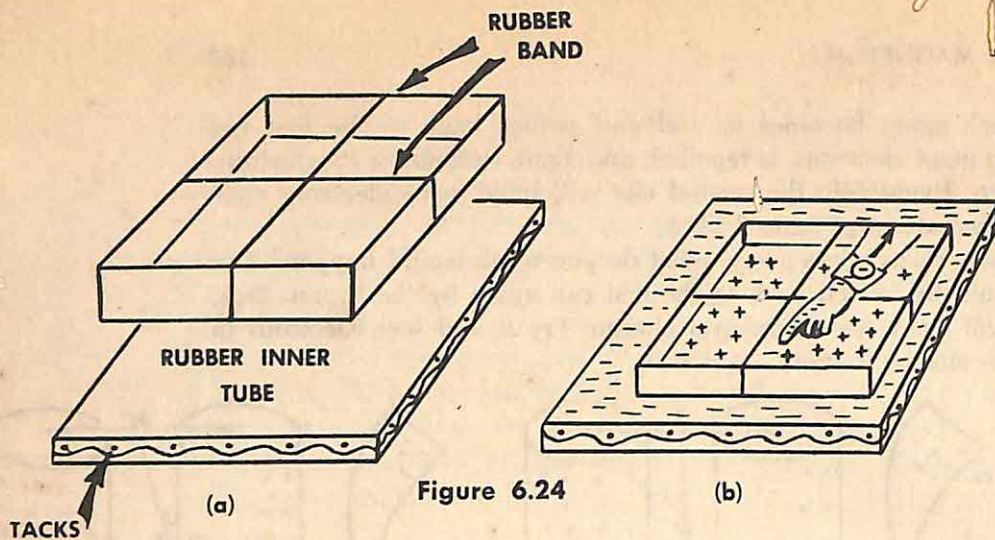


Figure 6.24

Discussion: The positively charged cake tin will attract electrons from the metal objects and your friend to create a spark. This spark can be clearly seen in a darkened room. See how large a spark you can make. It will surprise you to find out that over ten thousand volts can be generated with your electrophorus. *Volts* is the amount of push an electric current has. *Current* is a quantity of electrons that pass a given point per second. It is not dangerous because of the very small amount of current that is generated. Do you have an idea now how lightning is created?

C. CURRENT ELECTRICITY

1. Making a Complete Circuit With a Light Bulb Glow (Demonstration and Activity K-6)

Materials: One and one-half volt dry cell, flash light bulb ($1\frac{1}{2}$ volts), miniature lamp socket, insulated wire, and a small screw driver.

Procedure: Construct a circuit with a light bulb as illustrated in Figure 6.25.

Discussion: The light bulb will glow because the electrical current (electrons) flows in a complete circuit from the negative pole of the dry cell through the bulb to the positive pole of the dry cell. How can you stop the light from glowing?

Figure 6.25

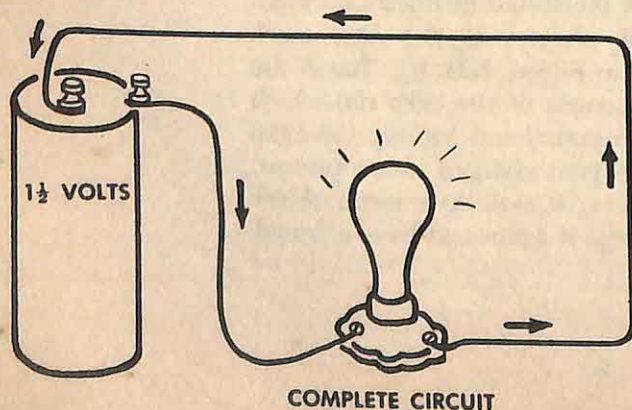
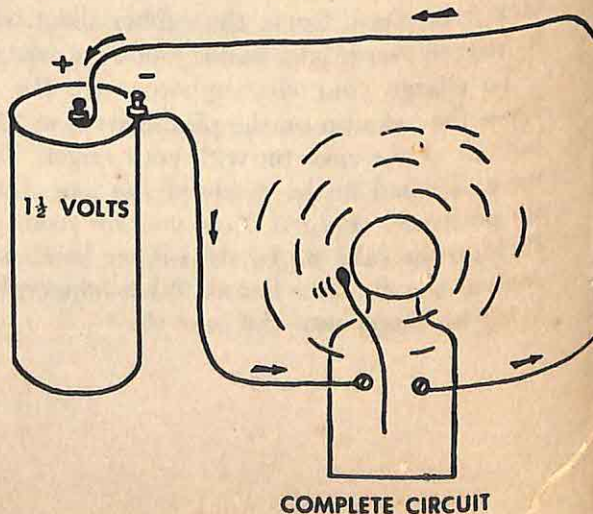


Figure 6.26



2. Making a Complete Circuit with a Door Bell (Demonstration and Activity K-6)

Materials: $1\frac{1}{2}$ volt dry cell, doorbell, insulated wire, and a small screw driver.

Procedure: Construct a circuit with a doorbell as illustrated in Figure 6.26.

Discussion: The doorbell will ring because the electrical current (electrons) flows through it in a complete circuit from the negative to the positive pole of the dry cell. How can you stop the bell from ringing?

3. Making a Conductor Tester (Demonstration and Activity K-6)

Materials: $1\frac{1}{2}$ volt dry cell, flash light bulb ($1\frac{1}{2}$ volts), miniature lamp socket, insulated wire, small screw driver, strips of aluminum, copper, steel, paper, plastic, cloth, rubber, wood, and two thumb tacks.

Procedure: Construct an electrical circuit with a gap in it as illustrated in Figure 6.27. Bridge the gap with the various materials mentioned above. Keep a record of those materials which allow the light bulb to glow and those which do not.

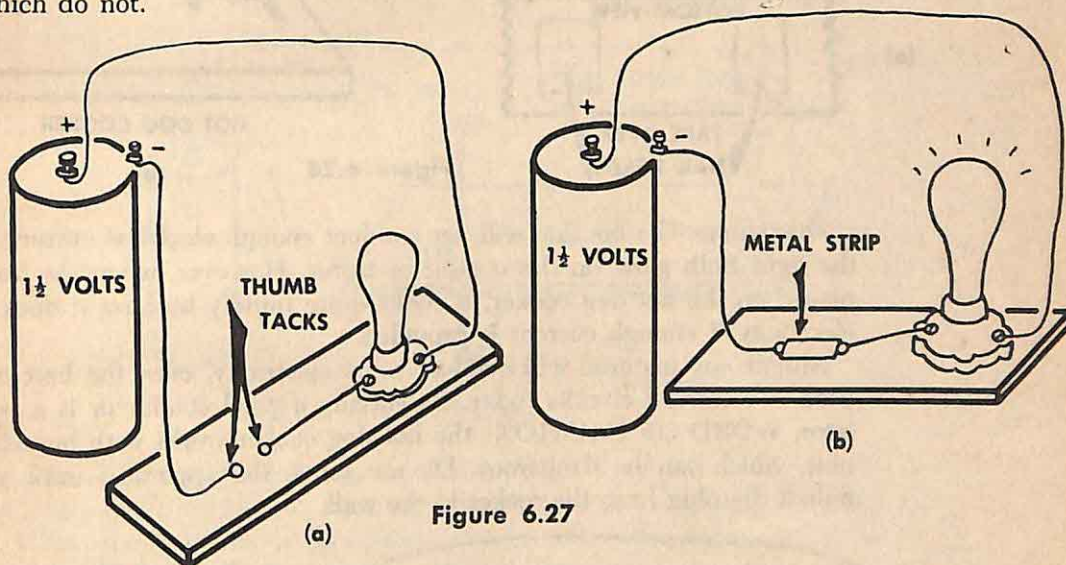


Figure 6.27

Discussion: Your conductor tester will help you find out which materials will conduct electricity. The metal strips will conduct electricity and the other materials will not. Materials that conduct electricity are known as *conductors*. Materials that do not conduct electricity are known as *insulators*.

4. Making a Hot Dog Cooker (Demonstration 4-6)

Materials: A conductor tester, hot dog, two steel nails, a wooden board, and an electric appliance cord with plug.

Procedure: Construct a hot dog cooker as illustrated in Figure 6.28(a).

Using the conductor tester, test the hot dog to determine whether or not it will conduct electricity. Does it? Place the hot dog on the hot dog cooker as illustrated in Figure 6.28(b). Insert the plug into the wall socket. Be careful! Do not touch the nails in the hot dog.

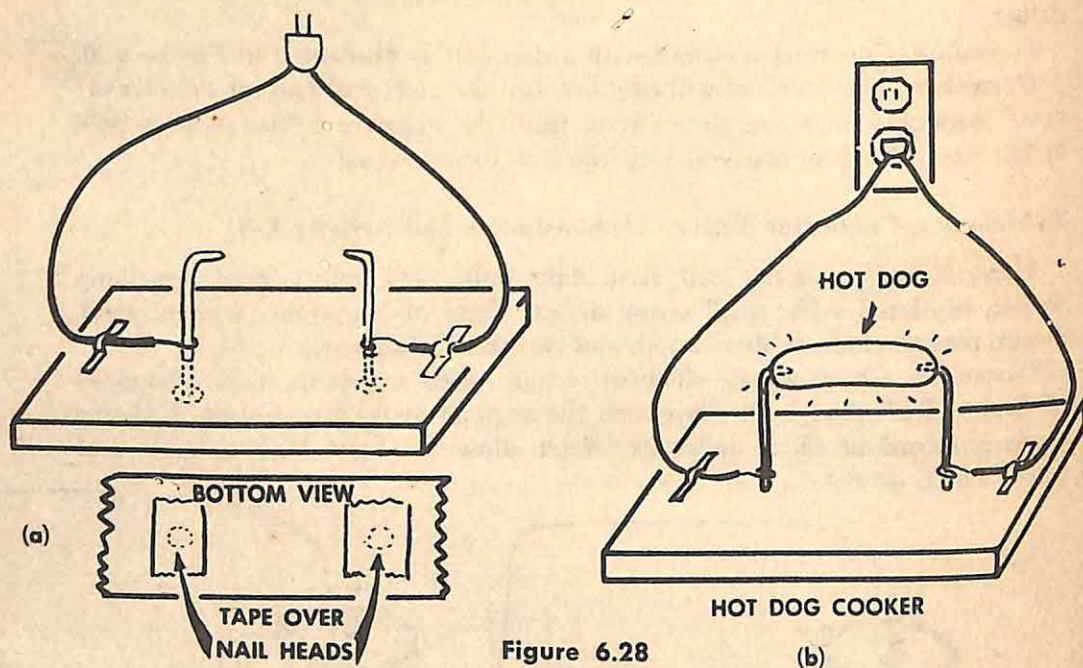


Figure 6.28

(b)

Discussion: The hot dog will not conduct enough electrical current to make the light bulb glow on the conductor tester. However, when the hot dog is placed on the hot dog cooker, it cooks quite rapidly because it does conduct electricity if enough current is provided.

Almost any material will conduct some electricity, even the best insulators used in electrical circuits today. Essentially a good conductor is a poor insulator. **WORD OF CAUTION:** the hot dog cooker works with household current, which can be dangerous. Do not touch the apparatus until you have pulled the plug from the socket in the wall.

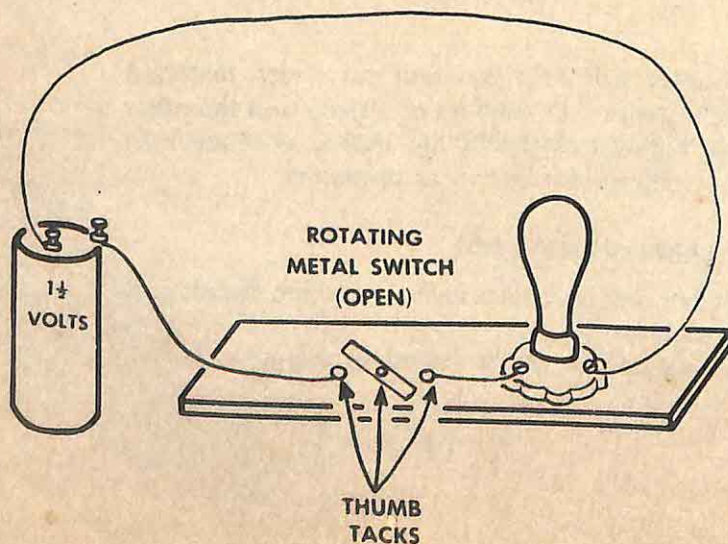


Figure 6.29

5. Making a Simple Switch (Demonstration and Activity K-6)

Materials: $1\frac{1}{2}$ volt dry cell, flashlight bulb ($1\frac{1}{2}$ volts), miniature lamp socket, insulated wire, small screw driver, strip of metal, and a wooden board.

Procedure: Construct a simple rotating switch as illustrated in Figure 6.29. What happens to the light bulb when the switch is closed? open?

Discussion: The metal strip conducts electricity when the switch is closed, and the light bulb glows. When the switch is open, the current flow stops and the light bulb goes out.

6. Making a Push Button Switch (Demonstration and Activity 2-6)

Materials: $1\frac{1}{2}$ volt dry cell, flashlight bulb ($1\frac{1}{2}$ volts), miniature lamp socket, insulated wire, small screw driver, strip of metal, and a wooden board.

Procedure: Construct a simple push button switch as illustrated in Figure 6.30. What happens to the light when the metal strip is pressed down with your finger? What happens when it is released?

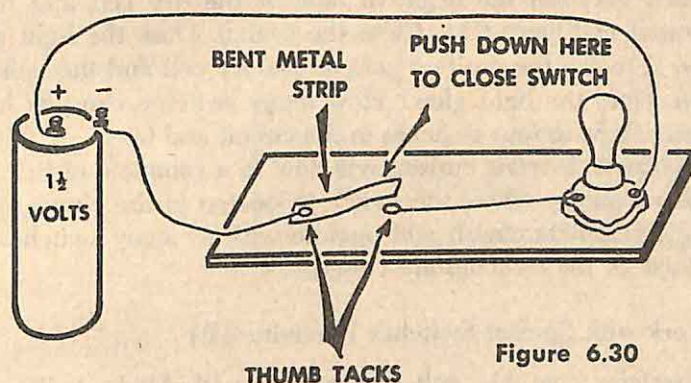


Figure 6.30

Discussion: The metal strip conducts electricity when pressed down to make contact with the steel thumb tack; the circuit is completed and the light glows. When the pressure on the metal strip is released, it springs up away from the thumb tack and the circuit is opened. Thus we have a push button switch. Investigate a "store bought" push button switch to see how it operates. Is it the same?

7. Flashing Light Code Club (Activity 2-6)

Materials: Push button operated light (Figure 6.30), copy of the International Morse Code, pencil, and paper.

Procedure: Operate the push button switch illustrated in Figure 6.30 as a telegraph key, using the International Morse Code. The dashes (—) are long duration flashes of the light and the dots (..) are short flashes of the light.

Write out your message in code before sending it to your friends. Have a pencil and paper handy to record the messages sent to you by your friends.

Discussion: The teacher can stimulate a lot of interest in electricity and electrical circuit by encouraging the children to form a secret code club. Membership is gained when the child makes a push button switch and places it in a complete circuit with a light bulb.

INTERNATIONAL MORSE CODE ALPHABET

A . _	F . . . _	K _ _ _	P . _ _ _	U . . _	Z _ _ . .
B _ . . .	G _ _ _	L	Q _ _ _ _	V . . . _	
C _ . . .	H	M _ _	R . . .	W . _ _	
D _ . .	I . .	N _ _	S . . .	X _ _ . .	
E .	J . _ _ _	O _ _ _	T _	Y _ . _ _	

8. Locating a Switch in a Simple Circuit (Demonstration 3-6)

Materials: Two simple switches, insulated wire, $1\frac{1}{2}$ volt dry cell, flashlight bulb ($1\frac{1}{2}$ volts), miniature lamp socket, and small screw driver.

Procedure: Construct a simple circuit as illustrated in Figure 6.25. Connect a switch between the negative pole of the dry cell and the light bulb as illustrated in Figure 6.31. Close the switch. Does the light glow? Connect a switch between the positive pole of the dry cell and the light bulb. Close the switch. Does the light glow? How many switches can you have in a circuit? Connect three or four switches in the circuit and try it.

Discussion: Electric current will flow in a complete circuit through a closed switch no matter where the switch is located in the circuit, and the light will glow. A complete circuit will operate with as many switches in it as desired, provided all the switches are closed.

9. Work with Special Switches (Activity 3-6)

Materials: Two $1\frac{1}{2}$ volt dry cells, two flashlight bulbs ($1\frac{1}{2}$ volts), two miniature lamp sockets, insulated wire, single-pole double-throw switch, and a small screw driver.

Procedure: After the children have had some experiences with constructing complete circuits and using switches, introduce a single-pole double-throw switch. Propose the following problem to them: using two dry cells, how many simple circuits can you make with one single-pole double-throw switch?

Discussion: Two simple circuits can be constructed as illustrated in Figure 6.32. Even third grade students have enjoyed the challenge of this problem and have been successful with it. When the switch is closed on one side, one light glows and the other does not. If the switch is thrown to the other side, the other circuit is completed, and the light bulb in it will glow. Of what practical value is a circuit like this?

10. Work with Special Switches (Activity 3-6)

Materials: One $1\frac{1}{2}$ volt dry cell, two flashlight bulbs ($1\frac{1}{2}$ volts), two miniature lamp sockets, insulated wire, and a single-pole double-throw switch.

CONNECT A SWITCH
HERE

CONNECT A SWITCH
HERE

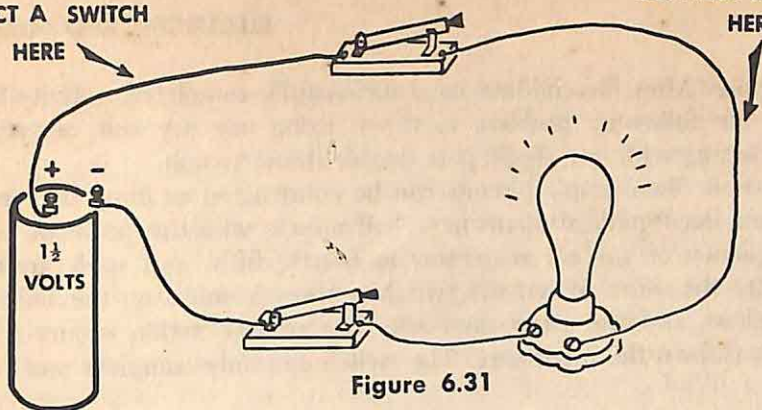


Figure 6.31

Figure 6.32

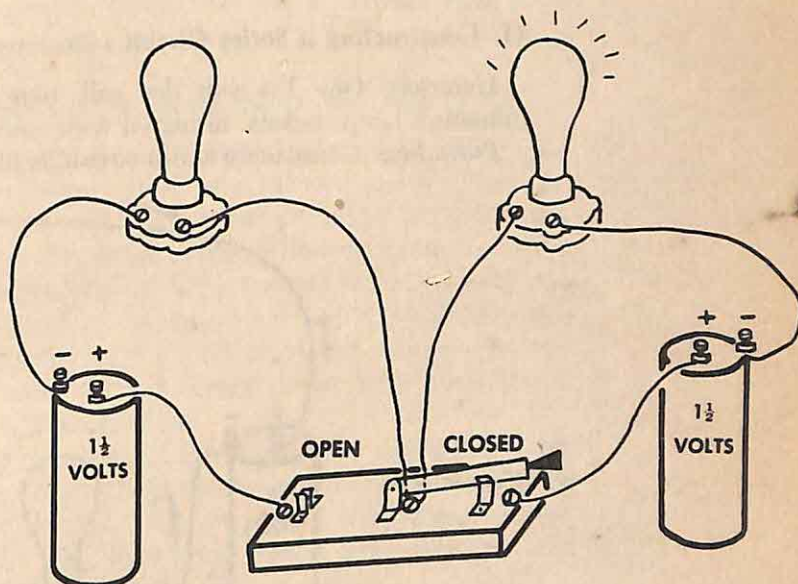
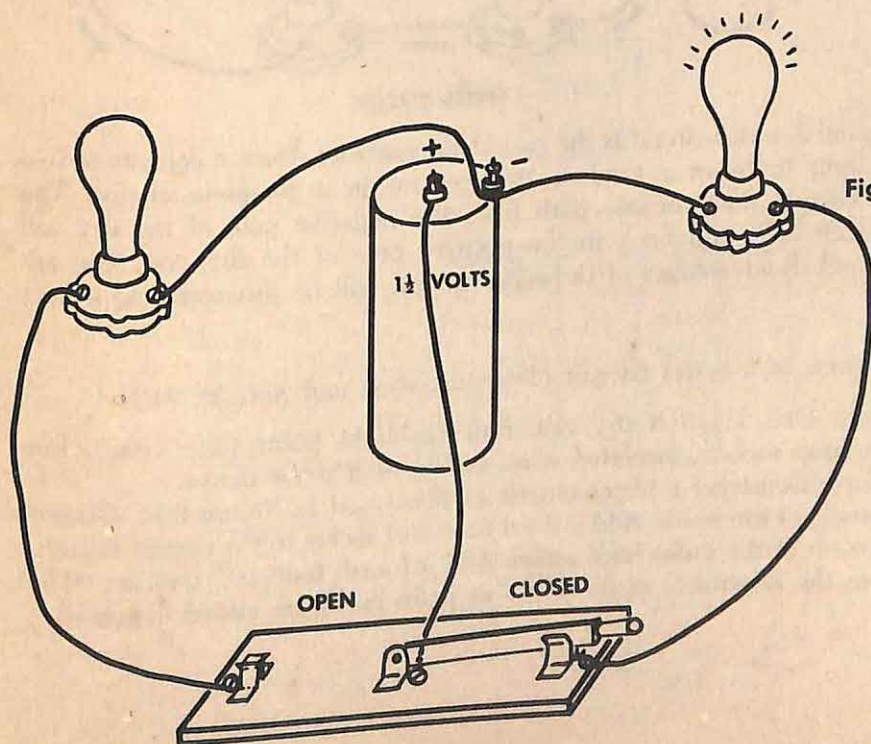


Figure 6.33



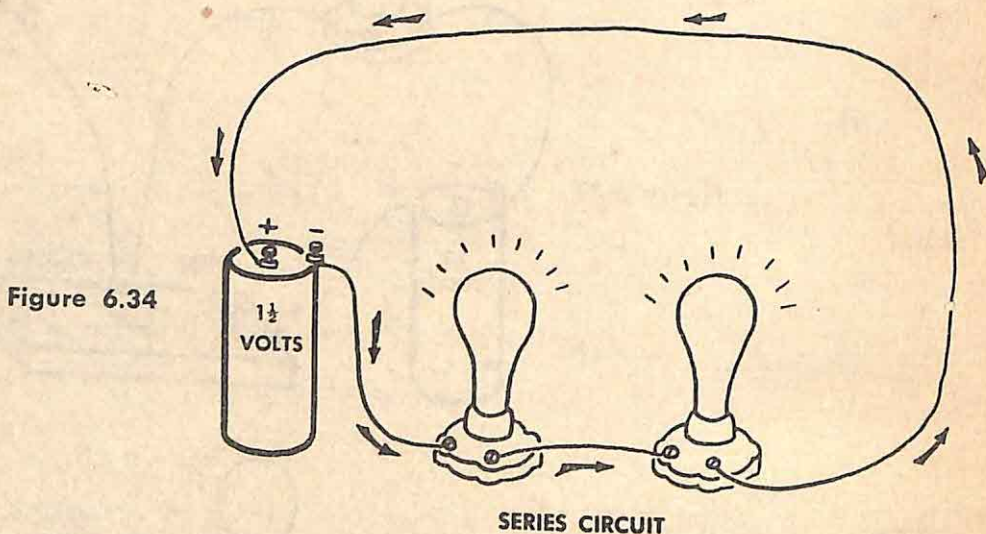
Procedure: After the children have successfully completed Activity 9 above, propose the following problem to them: using one dry cell, construct two simple circuits with one single-pole double-throw switch.

Discussion: Two simple circuits can be constructed as illustrated in Figure 6.33. Some third grade students have had success with this problem; however, the frequency of success is greater in fourth, fifth, and sixth grades. The results are the same. When the switch is thrown one way, the bulb in that circuit glows and the other does not. The reverse action occurs when the switch is thrown the other way. The switch can only complete one circuit at a time.

11. Constructing a Series Circuit (Demonstration and Activity 3-6)

Materials: One $1\frac{1}{2}$ volt dry cell, two flashlight bulbs ($1\frac{1}{2}$ volts), two miniature lamp sockets insulated wire, and a small screw driver.

Procedure: Construct a series circuit as illustrated in Figure 6.34.



Discussion: A series circuit is the easiest to construct. Here it consists of two or more light bulbs in a tandem arrangement in a complete circuit. The electrical current flows in one path from the negative pole of the dry cell through each bulb and back to the positive pole of the dry cell. The advantages and disadvantages of the series circuit will be discovered in a later activity.

12. Resistance in a Series Circuit (Demonstration and Activity 4-6)

Materials: One $1\frac{1}{2}$ volt dry cell, four flashlight bulbs ($1\frac{1}{2}$ volts), four miniature lamp sockets, insulated wire, and a small screw driver.

Procedure: Construct a series circuit as illustrated in Figure 6.34. Observe the brightness of the bulbs. Add a third bulb and socket to the circuit. Observe the brightness of the bulbs once again. Add a fourth bulb and a socket. What happens to the brightness of the bulbs as more bulbs are added in series?

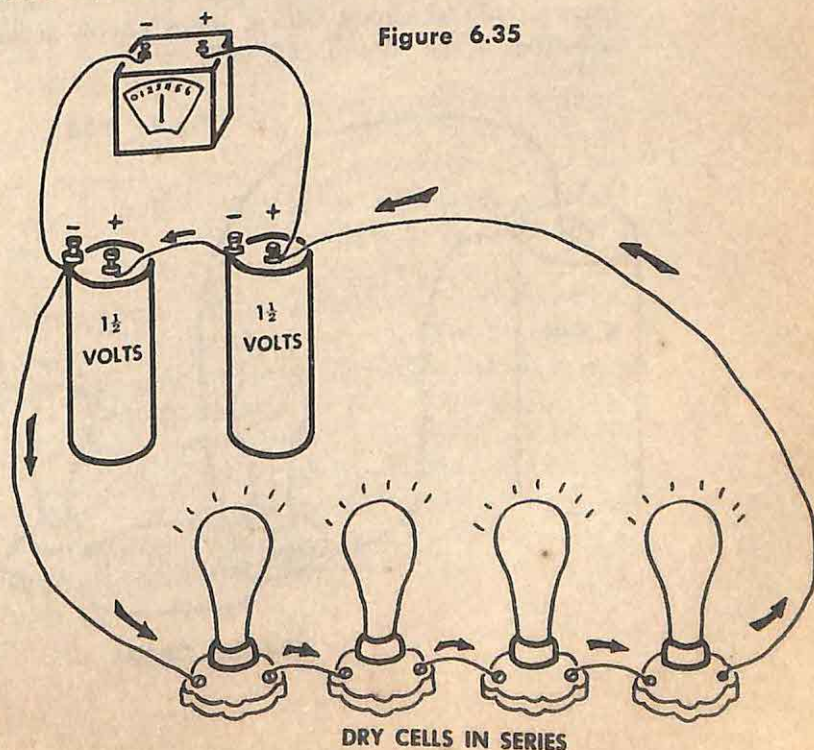
Discussion: As each bulb is added in series, the brightness of each bulb is finally decreased to a point where none of the bulbs appear to glow at all. The reason is simple. The electrical current must flow through each light bulb in which there is a high-resistance wire called a *filament*. The *number of electrons* which are allowed to pass through each light bulb is limited because of the resistance of the wire. The wire heats up to the point where it glows, producing light. The more current forced through the filament, the brighter the light. With the addition of light bulbs to the circuit, the resistance to the flow of electrons is increased. The more resistance in a series circuit, the less the current flow. The less current flow, the dimmer the bulbs become. One distinct disadvantage of series circuits is the decrease of current flow when more resistance is added to the circuit.

13. Increasing Power in a Series Circuit (Demonstration and Activity 4-6)

Materials: Two $1\frac{1}{2}$ volt dry cells, four flashlight bulbs ($1\frac{1}{2}$ volts), four miniature lamp sockets, insulated wire, a small screw driver, and a volt meter.

Procedure: Connect four bulbs in a series circuit as described in Demonstration and Activity 12 above. Ask the children the following question: what could we do to make the light bulbs brighter? The answer, of course, is to add another dry cell to increase the voltage. Connect another dry cell in series with the first dry cell as illustrated in Figure 6.35. What happens to the brightness of the bulbs? How many volts of energy do we have now? Use a volt meter as shown in Figure 6.35, to find out.

Discussion: The brightness of the bulbs is increased when another dry cell is connected in series. When two dry cells are connected in series, the energy (measured in volts) is multiplied by two. $2 \times 1\frac{1}{2}$ volts = 3 volts. We now have twice as much energy as before. The volt meter placed across the dry cell terminals, as shown in Figure 6.35, will verify this.



An adequate volt meter can be purchased from any scientific supply house for as little as \$5. Most high school physics laboratories use volt meters, which you might borrow.

How many volts of energy would you have if you used three dry cells? If you had four, and so on? One distinct advantage of series circuits is that voltage may be increased easily by adding dry cells in series.

14. Other Advantages and Disadvantages of Series Circuits

Materials: One $1\frac{1}{2}$ volt dry cell, two flashlight bulbs ($1\frac{1}{2}$ volts), two miniature lamp sockets, insulated wire, and a small screw driver.

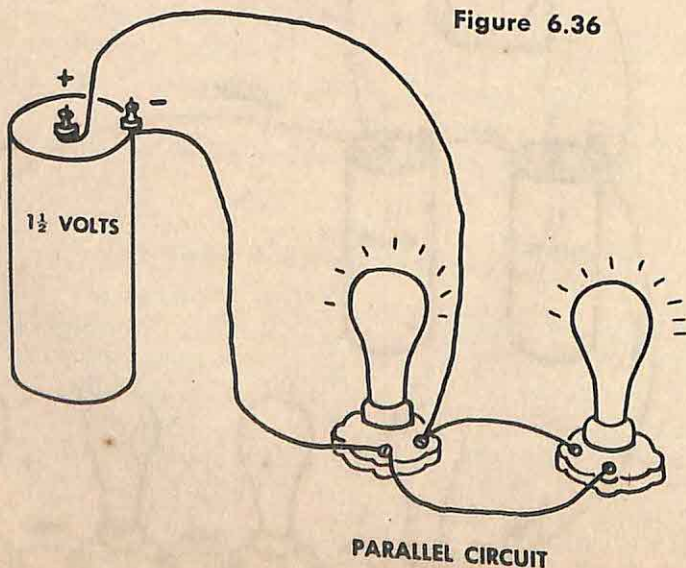
Procedure: Construct a series circuit as illustrated in Figure 6.34. Unscrew one light bulb. What happens? Replace the bulb and unscrew the other bulb. What happens? Disconnect any single wire from any one of the terminal screws, either on the dry cell or the miniature lamp sockets. What happens?

Discussion: When a light bulb is unscrewed from a socket or a wire is disconnected in a series circuit, all the lights go out because the circuit is broken. The electrical current must flow through one light bulb before it can get to the next one. Unscrewing a bulb from its socket is the same as disconnecting a wire in the circuit. The results are the same: the current flow stops and the light bulbs no longer glow. This is another disadvantage of a series circuit. An advantage of a series circuit, however, is the simplicity of its arrangement. Can you list the advantages and disadvantages of a series circuit? Can you think of others?

15. Constructing a Parallel Circuit (Demonstration and Activity 4-6)

Materials: One $1\frac{1}{2}$ volt dry cell, two flashlight bulbs ($1\frac{1}{2}$ volts), two miniature lamp sockets, insulated wire, and a small screw driver.

Procedure: Construct a parallel circuit as illustrated in Figure 6.36. Compare a parallel circuit with a series circuit arrangement. Trace the flow of electrons in the wire to each bulb.



Discussion: A parallel circuit is more complicated to construct. More wires are used, and the bulbs are connected differently than in a series circuit. Each bulb has a separate path (wire) through which the current (electrons) flows away from and back to the dry cell. Only enough current necessary to make each light bulb glow will reach it. With more than one path for the current to flow through, it will encounter in each path less resistance. The current does not have to flow through one bulb first before it reaches the next one in line, as it does in a series circuit.

16. Resistance in a Parallel Circuit (Demonstration and Activity 4-6)

Materials: One $1\frac{1}{2}$ volt dry cell, four light bulbs ($1\frac{1}{2}$ volts), four miniature lamp sockets, insulated wire, and a small screw driver.

Procedure: Construct a parallel circuit as illustrated in Figure 6.36. Observe the brightness of the bulbs. Add a third bulb and socket to the circuit. Observe the brightness of the bulbs once again. Add a fourth bulb and socket in the same manner. What happens to the brightness of the bulbs as more bulbs are added in parallel?

Discussion: The brightness of the bulbs remains the same as each bulb is added to the circuit. This is unlike the series circuit in which all the bulbs got dimmer as more resistance (light bulbs) was added. All the current does not have to pass through one light bulb (resistance) before it gets to the next one. Instead, the current flows in equal amounts through all the light bulbs simultaneously, which accounts for the constant brightness of all the bulbs. This is one definite advantage of a parallel circuit.

17. Advantages and Disadvantages of a Parallel Circuit (Demonstration and Activity 4-6)

Materials: One $1\frac{1}{2}$ volt dry cell, four light bulbs ($1\frac{1}{2}$ volts), four miniature lamp sockets, insulated wire, and a small screw driver.

Procedure: Construct a parallel circuit, as illustrated in Figure 6.36, with four bulbs in the circuit. Unscrew each bulb, one at a time. What happens? Disconnect a single wire between the third and fourth socket. What happens? Connect all wires again and then disconnect a wire between the second and third socket. What happens? Connect all wires again and then disconnect one wire between the first and second socket. What happens? Connect all wires once again and then disconnect one wire between the dry cell and the first socket. What happens?

Discussion: If a light bulb in a parallel circuit is unscrewed from its socket, the bulb no longer glows; however, the other bulbs are not affected and continue to glow. Each bulb has its own individual path through which electricity flows to it. The electrical current does not have to pass through one bulb before it reaches the next bulb. When a wire is disconnected between the third and fourth socket, the fourth bulb goes out. Its path for electrical current has been broken. When a wire is disconnected between sockets two and three, light bulbs three and four go out, and one and two remain lit. The circuit for three and four is broken. When a wire between sockets one and two is dis-

connected, light bulbs two, three, and four go out, but one remains lit. The circuit for bulbs two, three, and four is broken. If the circuit is broken between the dry cell and the first socket, all light bulbs go out. The current, in this case, cannot leave the dry cell to make a complete circuit.

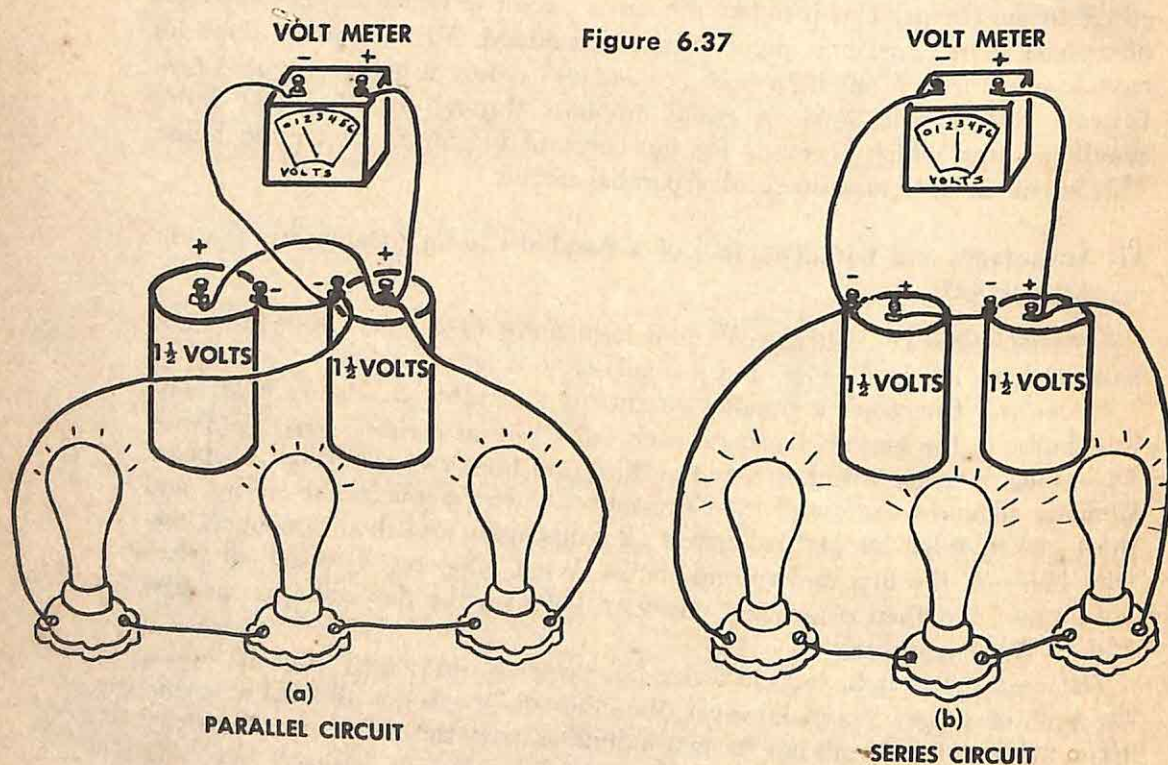
Two distinct advantages of a parallel circuit are: if one bulb is unscrewed from its socket, all the other bulbs do not go out; a wire disconnected between sockets does not necessarily mean that all the light bulbs will go out. For these reasons parallel circuits are used more often in home lighting circuits than series circuits.

18. Connecting Dry Cells in Parallel (Demonstration and Activity 4-6)

Materials: Four $1\frac{1}{2}$ volt dry cells, six flashlight bulbs ($1\frac{1}{2}$ volts), six miniature lamp sockets, insulated wire, a small screw driver, and a volt meter.

Procedure: Connect two dry cells in parallel, as illustrated in Figure 6.37(a), with three lights in series. Connect two dry cells in series, as illustrated in Figure 6.37(b), with three lights in a series. Observe the difference in the brightness of the bulbs in each circuit. Why is one circuit brighter than the other?

Figure 6.37



Discussion: The light bulbs in the circuit with the dry cells in series is much brighter. Remember? When dry cells are in series, voltage is added; thus we have three volts of push in this circuit. Use your volt meter to verify this. The light bulbs in the circuit with the dry cells in parallel are very dim. Use your

volt meter to measure the voltage in this circuit. It will be $1\frac{1}{2}$ volts. Dry cells in parallel do not increase voltage. They do, however, share the load and will last longer since each delivers less energy.

19. Making a Simple Flashlight (Demonstration and Activity 2-6)

Materials: One $1\frac{1}{2}$ volt flashlight size dry cell, insulated wire, flashlight bulb ($1\frac{1}{2}$ volts), and tape.

Procedure: Construct a simple flashlight as illustrated in Figure 6.38(a). Strip the insulation from each end of the wire as shown. Coil one end of the wire around the light bulb and tape the other end to the flat bottom of the dry cell as shown in Figure 6.38(b). Press the bottom of the bulb to the terminal knob on the dry cell and observe what happens.

Discussion: The light bulb glows when the bottom of the bulb is touching the terminal knob. A complete circuit is created. The metal bottom of the dry cell is the negative terminal of the cell, and the dry cell's knob is its positive terminal. Thus the wire connects the two terminals with the bulb in between, constituting a simple circuit.

20. Comparing the Size and Power of Dry Cells (Demonstration and Activity 3-6)

Materials: Various size $1\frac{1}{2}$ volt dry cells, insulated wire, and a volt meter.

Procedure: Using a volt meter, test the voltage of the various size dry cells as illustrated in Figure 6.39. What is the relationship of the size to the voltage of a dry cell?

Figure 6.38

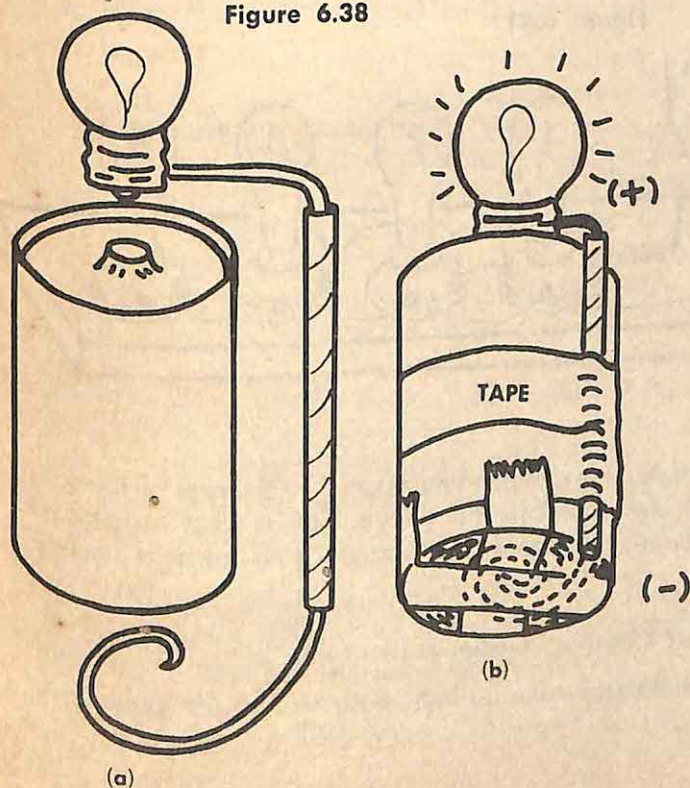
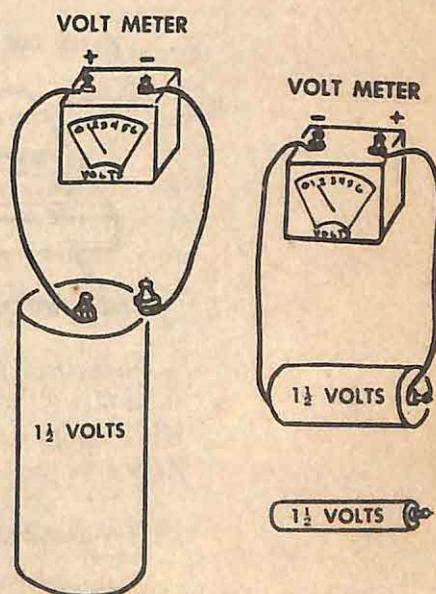


Figure 6.39



Discussion: The voltage of all the dry cells will be the same if they are fresh dry cells; otherwise there may be a slight difference in voltage.

21. Making an Electrical Fuse (Demonstration and Activity 3-6)

Materials: One $1\frac{1}{2}$ volt dry cell, metal foil from a chewing gum wrapper, two thumb tacks, and insulated wire.

Procedure: Strip the insulation from the ends of two wires and connect them to a metal foil fuse as illustrated in Figure 6.40(a). Cut a notch in the foil, as shown, so that there is just a narrow strip of foil connecting the two wires. Connect the other ends of the wire to the dry cell and observe what happens.

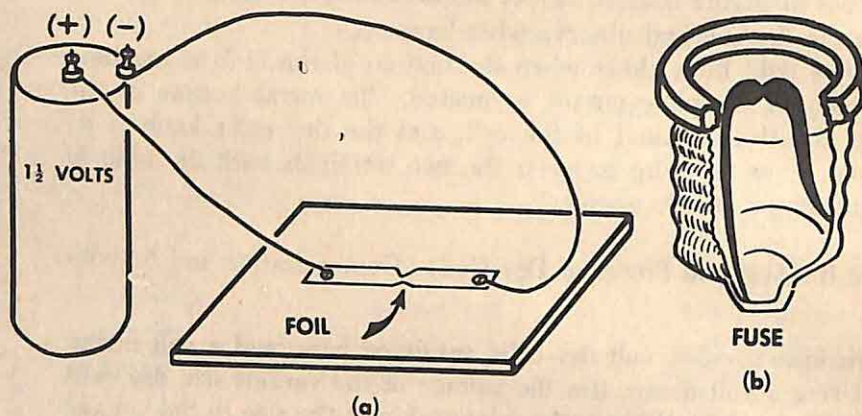
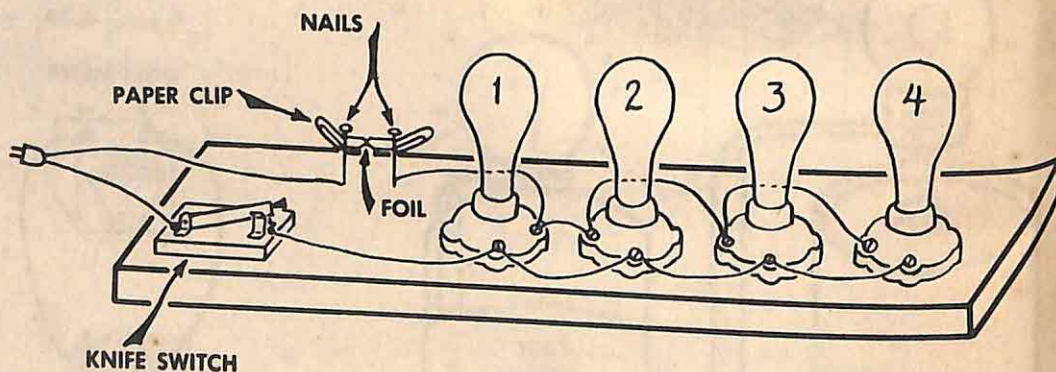


Figure 6.40

Figure 6.41



Discussion: After a minute or so, depending upon the thickness of the foil, the foil will heat up and melt, breaking the circuit. This is what happens to a household fuse when too much current flows through a circuit. It is a safety device to prevent fires.

22. Overloaded and Short Circuits (Demonstration 4-6)

Materials: Four household size ceramic light bulb receptacles, single pole

knife switch, insulated wire, two nails, four 200 watt bulbs, and a 30 inch pine board.

Procedure: Construct a parallel circuit with four household size ceramic light bulb receptacles and bulbs as illustrated in Figure 6.41. Include in the circuit a knife switch and a gap in the circuit formed by the two nails as shown. Cut a strip of metal foil from a gum wrapper and bridge the gap between the nails with the foil, securing each end with a paper clip. Cut the deepest notch in the strip of foil without cutting it in two. This will act as a fuse. Unscrew all the bulbs until they almost come out of the socket. *For safety purposes* follow the following procedure carefully. First open the knife switch. Then insert the plug into the socket and close the knife switch. Screw in each bulb slowly, one at a time, starting with the bulb closest to the switch until all the bulbs are lit. Observe the fuse. What happens to it and when?

Discussion: The fuse will "blow" sometime after the first bulb is lighted, depending on the size of the fuse. Each bulb will draw more current through the fuse as it lights. The more current that flows through the fuse, the hotter it becomes until it melts and breaks apart. This is commonly referred to as "blowing a fuse." In actuality we have an *overloaded circuit*. Overloaded circuits are common causes for blown fuses at home. They occur when people try to operate too many electrical appliances on one circuit, especially heating devices which require much current. For this reason fuses are necessary to prevent the overheating of wires which might cause a fire. NOTE: Be extremely careful when working with this apparatus; you are using household current which is dangerous. This demonstration is *not recommended* for students.

23. Liquids as Conductors (Demonstration 4-6)

Materials: Two household size ceramic light bulb receptacles, single pole knife switch, insulated wire, plug, one 25 watt bulb, one 75 watt bulb, several glass jars, distilled water, lemon juice, vinegar, salt, and sugar.

Procedure: Construct a parallel circuit with two household size ceramic light bulb receptacles and a knife switch as illustrated in Figure 6.42. Place a 25 watt bulb in the first socket and a 75 watt bulb in the second socket. *For safety purposes* perform the following operations carefully. First open the knife switch. Place the two insulation-free ends for the two wires in a jar of distilled water. Insert the plug in the socket and close the knife switch. Observe the two light bulbs. What happens? Pour some vinegar into the distilled water. Observe the light bulbs again. What happens? Pull the plug from the socket, open the knife switch, and remove the loose wires from the jar of vinegar and water. Fill another clean jar with distilled water and follow the same procedure as before with one exception. This time add lemon juice, salt, or sugar. For each substance follow the same procedure as before. Record the results of each experiment.

Discussion: The vinegar (acetic acid), the lemon juice (citric acid), and the salt are good conductors of electricity through which the electric current is allowed to flow and light the light bulbs. As these substances are introduced into the water, the 25 watt bulb glows first, then the 75 watt bulb as more of the substance is added. The molecules which make up each of these three

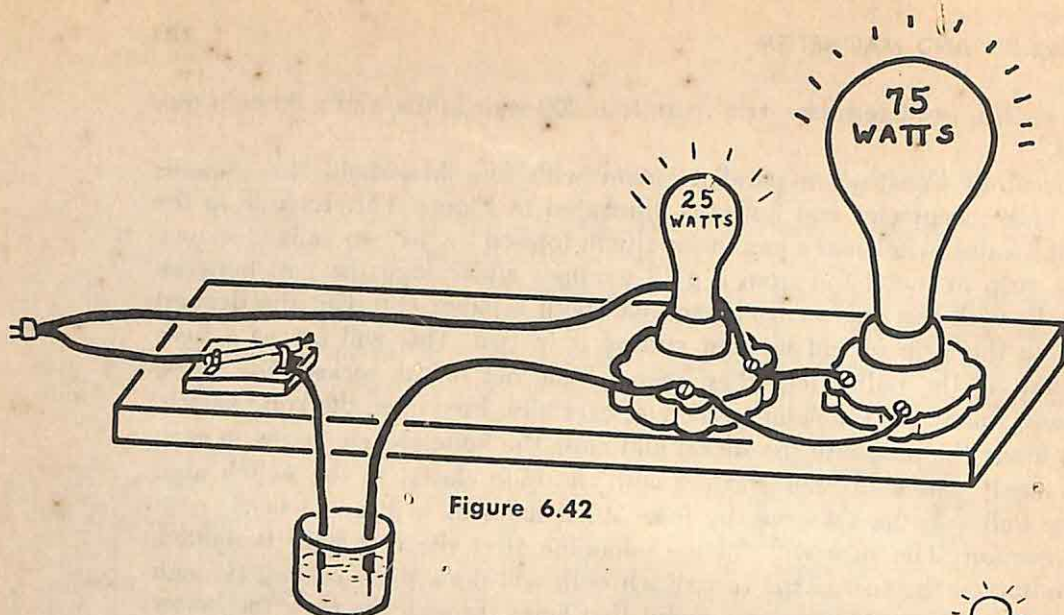


Figure 6.42

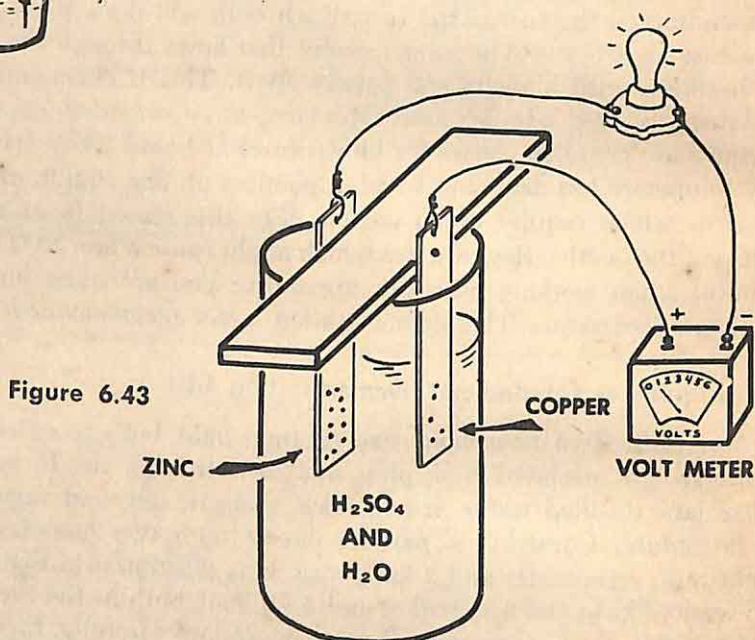


Figure 6.43

substances add to the conductivity of the water. The sugar molecules did not add to the conductivity of the distilled water; therefore, the lights did not glow. The fewer the impurities in the water, the lower the electro-conductivity of the water. For this reason it is important to use pure distilled water in a car battery.

24. Making a Wet Cell Battery (Demonstration and Activity 4-6)

Materials: Glass jar, water, dilute solution of sulfuric acid, zinc strip, copper strip, insulated wire, wooden stick, volt meter, flashlight bulb ($1\frac{1}{2}$ volts), and a miniature lamp socket.

Procedure: Fill a quart jar about $\frac{3}{4}$ full with water and add about $\frac{1}{4}$ cup

of dilute sulfuric acid. Construct a galvanic cell, as illustrated in Figure 6.43, and connect it in series with a $1\frac{1}{2}$ volt light bulb and a volt meter. This cell will operate better if the ends of the wire are soldered firmly to the zinc and copper plates. Ask your school shop teacher or custodian to help you. An alternative plan would be to drill a hole in the plate and twist the wire around the end of the plate as shown in Figure 6.43. Does the light glow? How many volts are indicated on the volt meter?

Discussion: An electric current having about one volt of push will be generated, which may or may not be enough to light the bulb. In any event the bulb will not glow very brightly. The volt meter will read about one volt. A wet cell battery, or a *voltaic* cell, has been made. Electricity has been generated by a chemical reaction involving the copper, zinc, and the sulfuric acid

25. The Inside of an Electric Light Bulb (Demonstration and Activity 4-6)

Materials: One burned out household light bulb, a cloth, and a hammer.

Procedure: Wrap a light bulb in a cloth and gently tap it with a hammer to break the glass. Do not strike it too hard or you might destroy the wires inside, which you are to display to the children. With a pair of work gloves on, remove the broken glass from around the core. Trace the flow of electric current through the wires in the bulb.

Discussion: Figure 6.44 will give you an illustration of what you might expect to find.

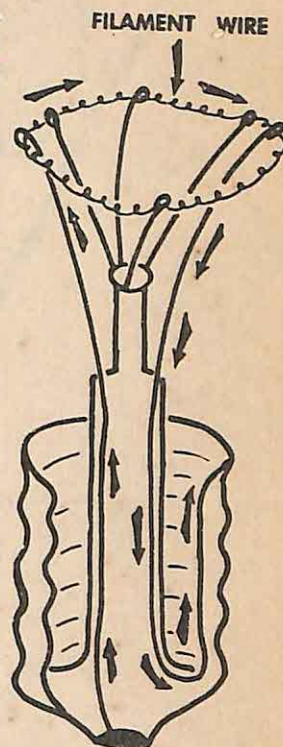


Figure 6.44

D. RELATIONSHIP BETWEEN MAGNETISM AND ELECTRICITY

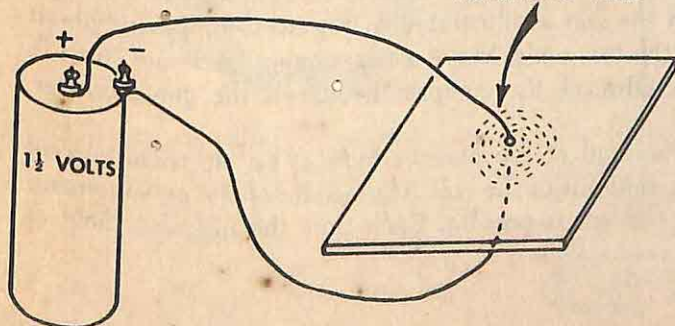
1. The Magnetic Field Around a Conductor (Demonstration and Activity 4-6)

Materials: One $1\frac{1}{2}$ volt dry cell, insulated wire, sheet of cardboard, and iron filings.

Procedure: Pass a single wire conductor through a hole in a sheet of cardboard and connect the ends to a dry cell as illustrated in Figure 6.45. Sprinkle some iron filings on the cardboard around the wire and tap the cardboard gently with your finger. What do you observe?

Figure 6.45

IRON FILINGS SHOWING
MAGNETIC FIELD



Discussion: The iron filings form the pattern of the lines of force of the magnetic field around the conductor through which electrical current is flowing. They appear much the same as the magnetic lines of force around a magnet as observed in Section A, Activities 8 and 9 of this chapter.

2. The Magnetic Field Around a Coil (Demonstration and Activity 4-6)

Materials: One $1\frac{1}{2}$ volt dry cell, insulated wire, sheet of cardboard, and iron filings.

Procedure: Thread a length of insulated wire through a sheet of cardboard to form a coil as illustrated in Figure 6.46. Sprinkle some iron filings around the coil and connect the ends of the wire to the dry cell. Tap the cardboard gently with your finger. What do you observe?

Discussion: The iron filings form the pattern of the lines of force of the magnetic field around the coil of wire as shown in Figure 6.46. The pattern formed is much like that of a bar magnet. We see more evidence of the similarity of magnetism and electricity.

3. Making a Galvanometer (Demonstration and Activity 4-6)

Materials: Roll of insulated wire, block of wood, sheet of cardboard, compass, needle, rubber band, tape, and a $1\frac{1}{2}$ volt dry cell.

Procedure: Set up the equipment as illustrated in Figure 6.47(a). Use 50 to 60 turns of wire in the coil. Tape the coil to the cardboard backing as shown, and adjust the direction of the coil until the compass needle is *parallel* to it. Connect the ends of the wire to the $1\frac{1}{2}$ volt dry cell and observe the compass needle. What happens? Why?

Discussion: A simple galvanometer has been constructed which can be used to indicate the presence of electrical current in the coil. The needle of the compass will swing to a position perpendicular to the coil, indicating the magnetic field created by the current flow.

Figure 6.47(b) illustrates how a sewing needle and a rubber band can be used as a substitute for a compass needle.

When using this type of galvanometer, be sure there are no magnets which might affect the compass needle in the immediate vicinity.

4. Generating Electricity with a Magnet (Demonstration and Activity 4-6)

Materials: Homemade galvanometer, coil of wire, and a bar magnet.

Procedure: Construct a simple galvanometer as illustrated in Figure 6.47. Do not connect the dry cell to coil. Instead, connect another coil of wire (40 to 60 turns) to the ends of the coil as illustrated in Figure 6.48, leaving about two feet of wire between the two coils. Move a bar magnet back and forth in the second coil as shown. Observe the compass needle of the galvanometer. What happens? Why?

Discussion: The magnetic field of the magnet *induces* an electrical current in the coil as it is moved in and out of the coil. The needle of the galvanometer indicates that a pulsating current is present. Each time the magnetic field of

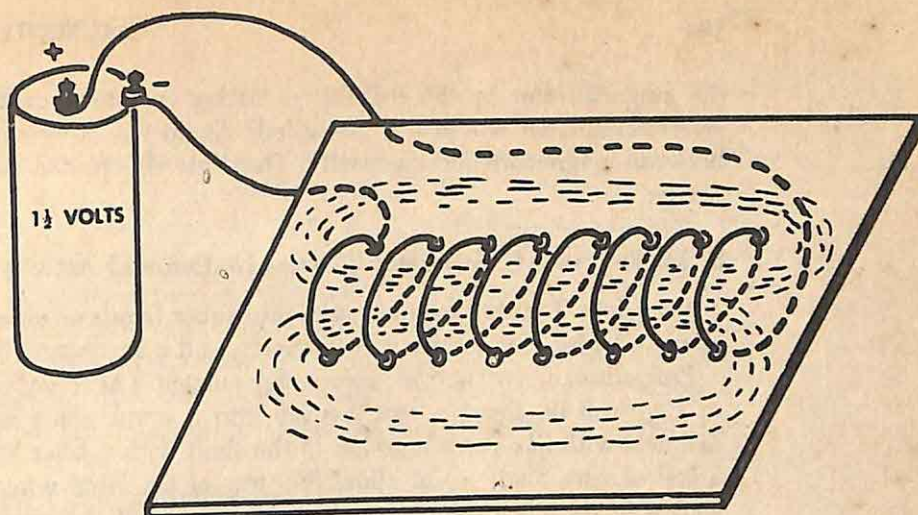


Figure 6.46

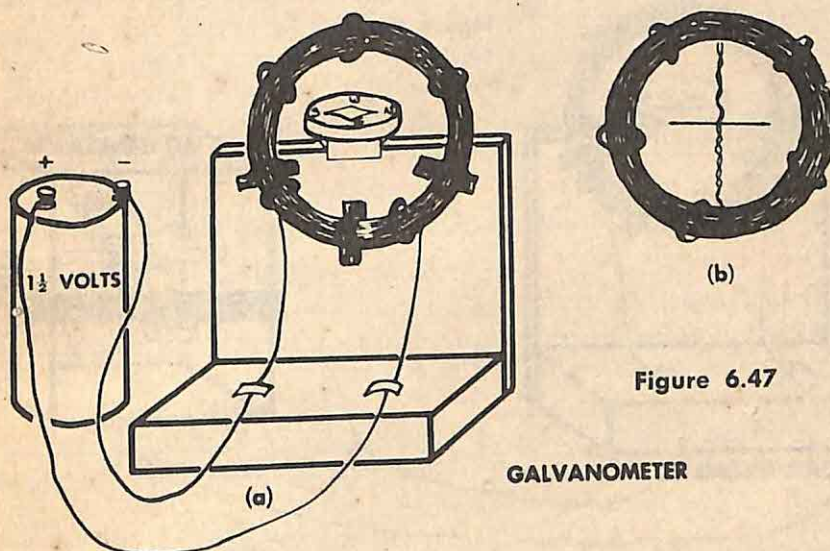


Figure 6.47

GALVANOMETER

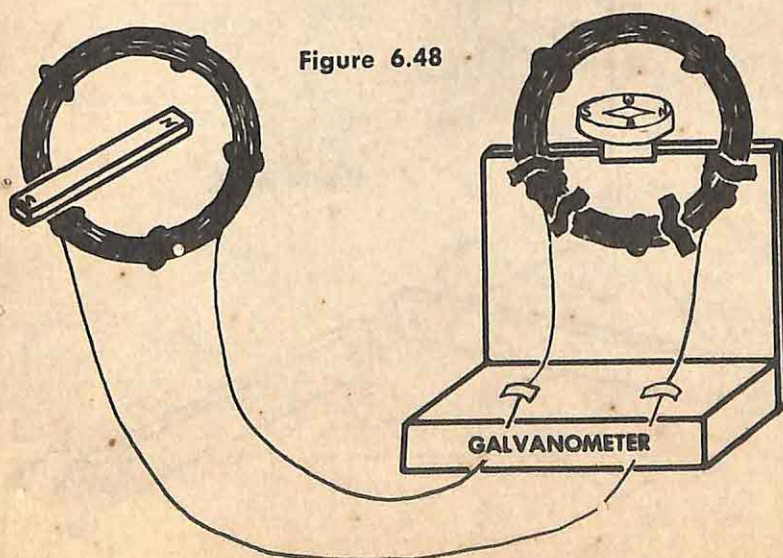


Figure 6.48

GALVANOMETER

the magnet is cut by the coil this pulsating current is created. What kind of electrical current would this be called? Again we experience the relationship between magnetism and electricity. This time we created electricity with magnetism.

5. Making an AC Generator (Demonstration and Activity 4-6)

Materials: Two bar magnets, several rubber bands or tape, wire coat hanger, insulated wire, homemade galvanometer, and a cardboard box.

Procedure: Construct an alternating current (AC) generator as illustrated in Figure 6.49. Bend a coat hanger into a crank shaft and attach two bar magnets with *like poles* together to the shaft with rubber bands or tape. Wrap a coil of wire made up of about 30 turns of insulated wire around the box as shown in the illustration. Attach the two ends of the wire to the homemade galvanometer illustrated in Figure 6.47. Turn the crank and watch the compass needle of the galvanometer. What do you observe? Why?

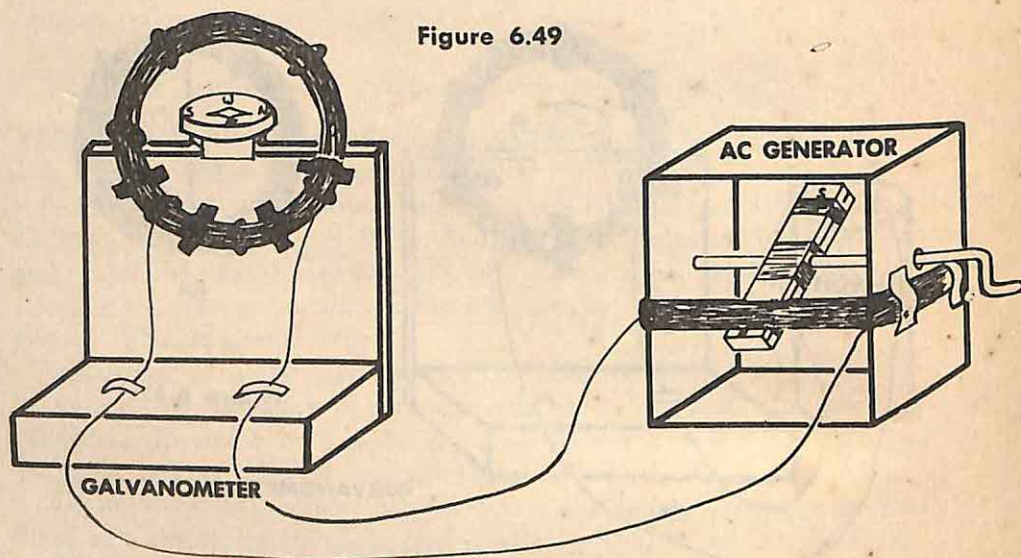


Figure 6.49

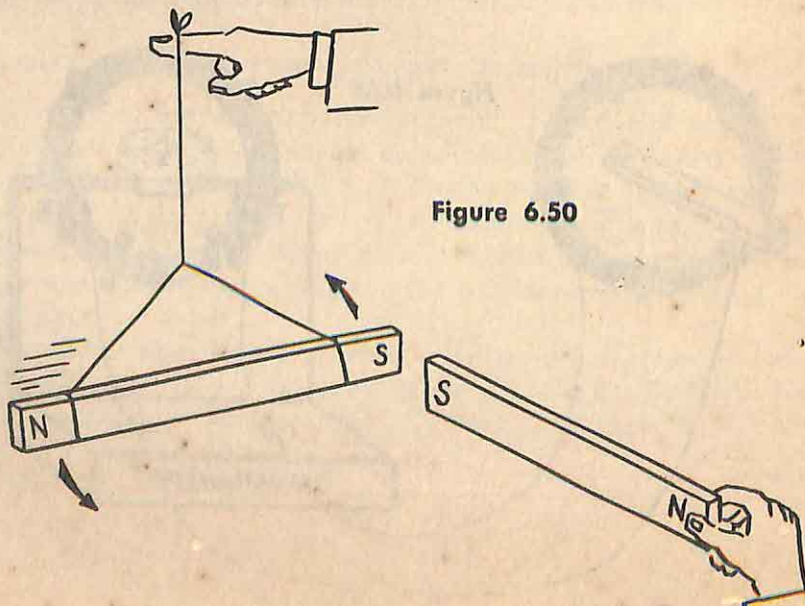


Figure 6.50

Discussion: The needle on the galvanometer will swing in a pulsating manner, indicating a pulsating current. As the poles of the magnet swing around and their magnetic field is cut by the coil of wire, a small current is induced in the coil, causing the needle to move. This pulsating current is known as *alternating current* or *AC current*. If you crank the handle very fast, the needle will not swing as far as it pulsates, indicating a steadier flow of current. The AC current used in your home is pulsating sixty times every second so that it gives a rapid pulsating flow of current which is so swift and slight that a meter cannot respond to each pulse of current. This allows your lights to glow without flickering. It also allows AC motors to run smoothly. We have seen again how magnetism and electricity are related to each other.

6. A Simple Motor (Demonstration and Activity 4-6)

Materials: Two bar magnets and string.

Procedure: Suspend a bar magnet from a string so that it swings freely as illustrated in Figure 6.50. Bring another bar magnet near the free swinging magnet so that like poles repel each other. As the swinging magnet rotates, attempt to speed up its speed of rotation by continually trying to bring repelling like poles together.

Discussion: This is a simple motor, operating on the principle of repelling magnets. Will attracting poles of two magnets produce the same results?

7. Making a Simple Electric Motor (Demonstration and Activity 4-6)

Materials: A "Whiz Electric Motor Set."

Procedure: One of the best ways to learn about electric motors is to build one. A simple, easy to construct motor can be purchased from the Eltro Company, P. O. Box 171, Deer Park, New York, for 35 cents each. Just ask for a "Whiz Electric Motor Kit."

A diagram of the motor is shown in Figure 6.51. What function do the various parts shown play in the operation of the motor?

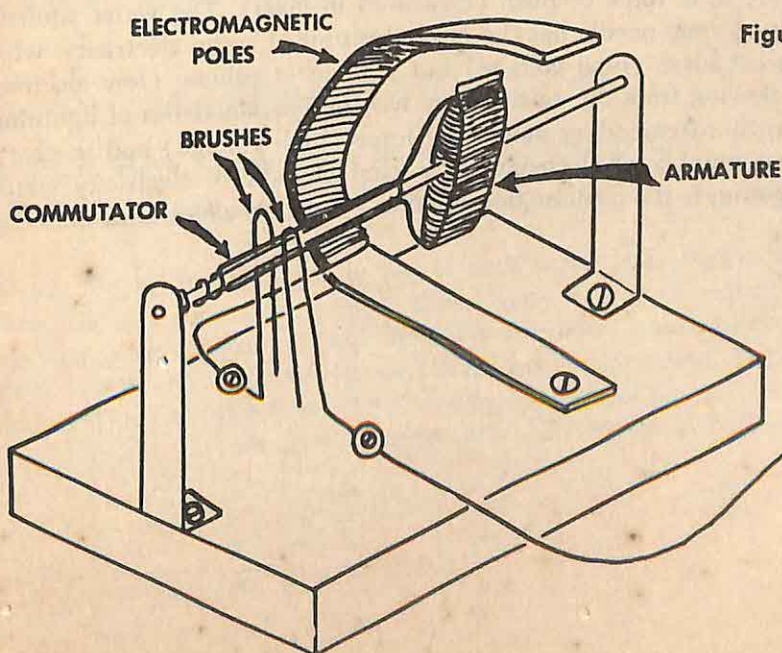


Figure 6.51

Discussion: The parts of the motor serve the following functions. The electromagnetic *poles* provide the motor with the repelling poles. The *armature* is a free swinging magnet which is repelled by the pole magnet. The armature is an electromagnet which changes its north and south poles so that it will be repelled by the pole magnets and continue to turn. The rapid change in the north and south poles is caused by changing the direction of the current flow in the wires around the armature. If the flow of current goes one way, you will have a north pole on one end and a south pole on the other end. If the current changes direction, the poles will change too. The *commutator* changes the direction of the flow of electricity as the armature shaft rotates. The *brushes* are the conductors which carry the flow of electrical current to the commutator and armature.

8. The Difference Between Current Electricity, Static Electricity and Lightning (Demonstration 4-6)

Materials: Milk bottle, garden hose or faucet hose attachment, hypodermic syringe with needle, and water.

Procedure: An interesting water analogy can be made to compare current electricity as we know it in our homes, static electricity, and lightning. All three kinds of electricity involve the movement of electrons. They differ only in the number of electrons involved and the force applied to make the electrons move. Fill a milk bottle and a hypodermic syringe with water. Attach a garden hose with a nozzle to a faucet. Tilt the milk bottle and pour the water out into a sink. What do you observe about the force of flow and amount of water involved? Push the plunger of the hypodermic needle quickly to discharge the water through the needle. What do you notice about the force of flow and amount of water involved? Turn on the faucet to discharge the water through the nozzle. What do you notice about the force of flow and amount of water involved?

Discussion: The water flowing from the milk bottle has the characteristics of current electricity, which flows in great volume (many electrons) but with relatively little force or push (measured in *volts*). The water squirting from the hypodermic needle has the characteristics of static electricity, which flows with great force (high voltage) but with little volume (few electrons). The water flowing from the garden hose has the characteristics of lightning, which flows with a tremendous amount of force (high voltage) and in great volume (a great number of electrons). The characteristic of electricity which makes it dangerous is the combination of $\text{volts} \times \text{current}$, which is available power.

VII

Lifting and Moving Using Simple Machines

Man is forever seeking new ways to perform work more easily and quickly with machines. Almost everyone of these machines is made up of a basic group of simple machines in one form or another. From the simple wedge used by the woodsman to split logs to the most intricate computer, simple machines, such as the lever, the pulley, the inclined plane, the roller and the wheel, are used to either speed up the work or to make the work easier to perform.

The use and advantages of these simple machines can easily be studied by elementary school students at all levels.

In this chapter, as in some of the previous chapters, we find a quantitative study as well as a qualitative study.

A. USING SIMPLE MACHINES

1. Rollers Help Move Things (Demonstration and Activity K-6)

Materials: Several books, several hexagonal pencils, and several round pencils.

Procedure: Stack several books on top of each other and attempt to push them along the flat surface of a desk. Place some hexagonal pencils under the books and push them across the desk. Do the books move more easily? Try some round pencils under the books. Do the books move more easily now?

Discussion: There is little or no difference in the ease of moving the books across the desk with the hexagonal pencils under the books. The round pen-

cils, however, make a considerable difference in the ease of moving the books. These devices are known as *rollers*. The roller is one of the basic simple machines.

2. Rollers Help Move Heavy Things (Demonstration and Activity K-6)

Materials: Large heavy carton and wooden rollers or lengths of pipe.

Procedure: Have one boy attempt to push a heavy carton across the floor. Have another boy help him and then another until they can move the carton. With help from the teacher place several rollers under the box and have the smallest girl in the classroom attempt to push the box across the room. What happens?

Discussion: The small girl can easily push the box with the rollers under it across the floor. The rollers reduce the friction between the floor and the flat surface of the box. This is another demonstration of the use of the simple machine known as *rollers*.

3. Wheels Make Things Move Fast (Demonstration and Activity K-6)

Materials: Small cardboard carton, two nails, two rubber bands, and two thread spools.

Procedure: Attempt to push a small cardboard carton across a smooth table top or floor. Measure the distance it travels after one short shove. Add two thread spool wheels to the carton as illustrated in Figure 7.1. Now push the carton across the smooth table top or floor with the same force (or as close to the same force as possible) and measure the distance it traveled. What are the results?

Discussion: The carton traveled a considerably greater distance at a greater speed with the thread spool wheels. Wheels are simple machines too.

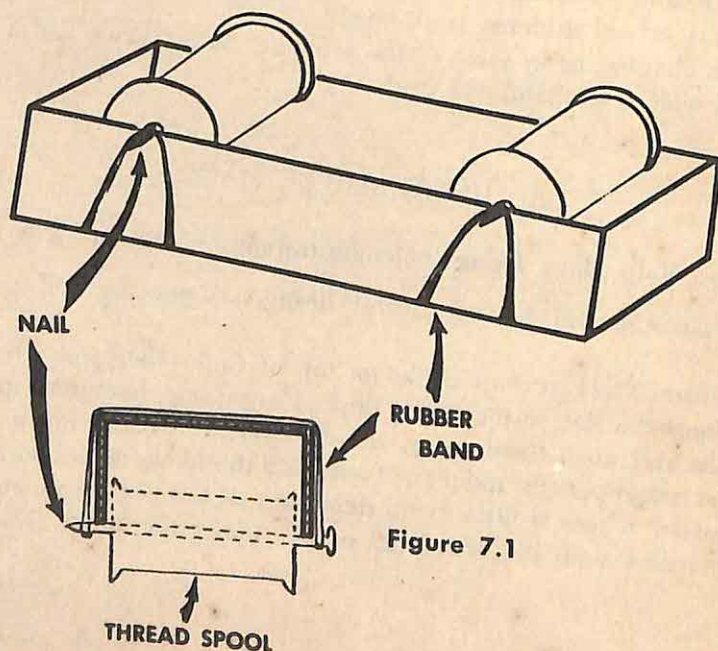


Figure 7.1

4. Using a Wagon to Move Heavy Things (Demonstration and Activity K-6)

^o *Materials:* Large heavy carton and a toy wagon.

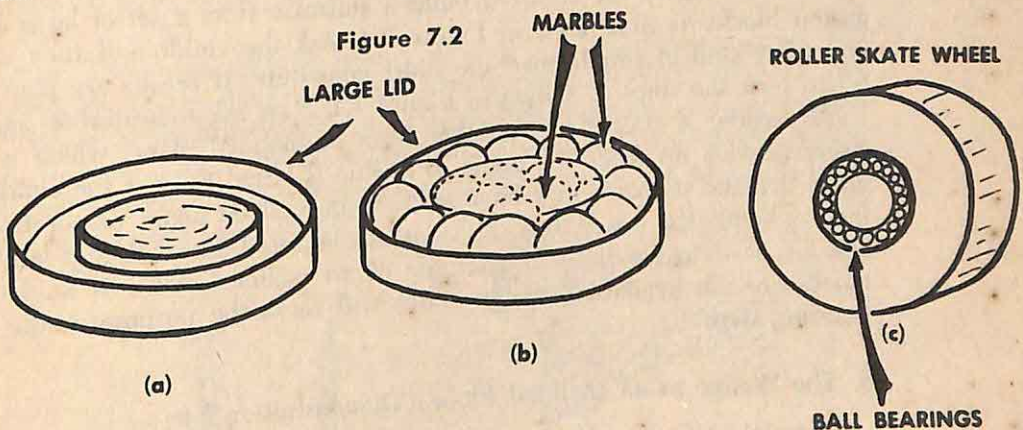
Procedure: Have one boy attempt to push a heavy carton across the floor. Have another boy help him and then another until they can move the carton. With help from the teacher lift the carton onto the wagon and have the smallest girl in the classroom attempt to pull or push the wagon across the floor. What happens?

Discussion: The small girl can easily push the box across the floor with the aid of the wheels on the wagon. Like rollers, wheels help to reduce friction, only they reduce to a greater extent and make the job of pushing the wagon very easy.

5. Ball Bearings Reduce Friction in Turning Wheels (Demonstration and Activity 2-6)

Materials: Roller skate, two jar lids, and several marbles of the same diameter.

Procedure: Place a small jar lid inside a larger jar lid as illustrated in Figure 7.2(a). Balance yourself on one foot on the smaller jar lid and try to spin your body by pushing with the other foot. What happens? Place some marbles of equal size into the larger jar lid and place the smaller jar lid, hollow side down, over the marbles, as illustrated in Figure 7.2(b), with a row of marbles between the two lips of the jar lids as shown. Balance yourself on the smaller jar lid with one foot and try to spin your body around. Be careful! What happens?



Discussion: The friction between the smaller lid and the larger lid is too great to allow easy spinning. However, after the marbles were added between the lids, spinning was easy and smooth. The marbles act like ball bearings in a roller skate wheel, which reduce the friction between the wheel and the axle of the wheel. (Display the roller skate wheel bearings.) Only a very small

surface of each marble, or steel ball in a roller skate wheel, is exposed to friction at any one time. For this reason spinning your body on one foot over the marble ball bearings is made very easy. Investigate the steel ball bearings of a roller skate, as illustrated in Figure 7.2(c), to see how they operate. Ball bearings allow wheels to spin faster and smoother.

6. The Inclined Plane (Demonstration and Activity K-6)

Materials: Toy truck, sheet of stiff cardboard or a wooden board, and a table.

Procedure: Propose the following problem to the children in your classroom! How can we "drive" the toy truck from the floor to the top of the table without lifting it? What results can you expect?

Discussion: The solutions for this problem will range from "attaching rockets to the truck" to "using a ramp," depending, of course, on the grade level. The most desirable solution, of course, is the ramp, often referred to as an *inclined plane*. Obtain a stiff sheet of cardboard, masonite, ceiling board, or a wooden plank and have the children make an inclined plane or ramp which extends from the floor to the top of the table. Then have them "drive" the toy truck up onto the top of the table as illustrated in Figure 7.3. An inclined plane is a basic simple machine too. Can you think of some everyday experiences involving inclined planes?

7. Other Inclined Planes (Demonstration and Activity K-6)

Materials: Large kindergarten blocks, small step ladder, and a wooden board.

Procedure: Have the children build a staircase from a set of large kindergarten blocks as illustrated in Figure 7.4. Ask the children if they can tell you what kind of simple machine stairs constitute. If results are poor, lay a board over the steps as shown in Figure 7.4. Now ask the question again.

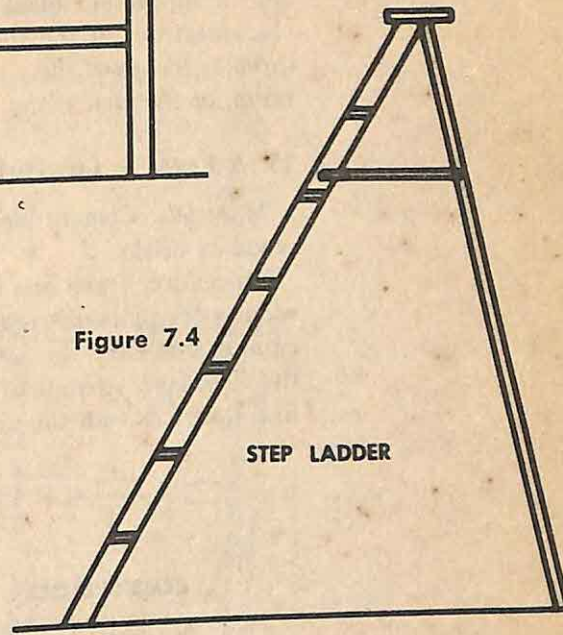
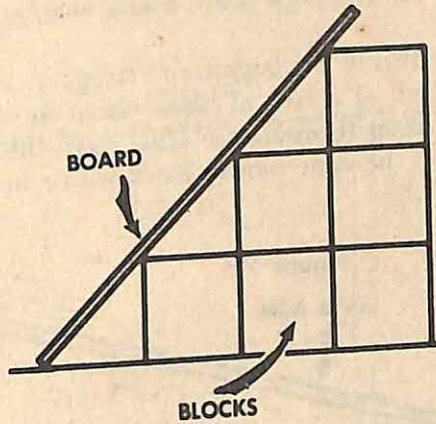
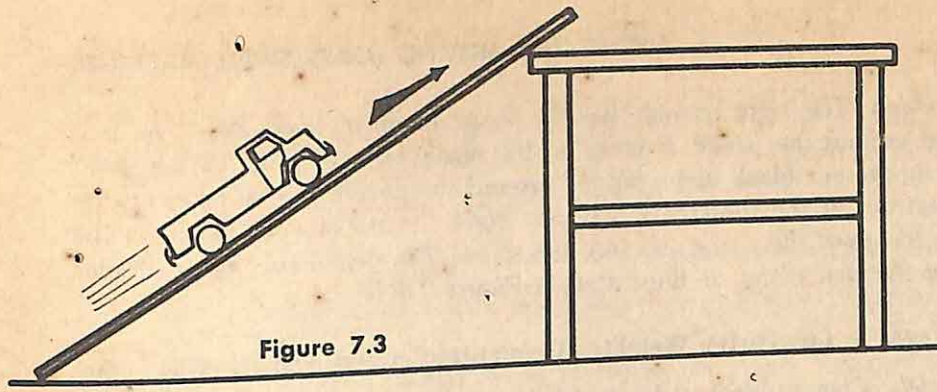
Discussion: A staircase is another form of inclined plane, which is much easier to walk up when the angle of incline is large. Even if the children do guess that the staircase they have made is an inclined plane, demonstrate this fact by laying the board over the steps as suggested above. A step ladder can also be used to illustrate an example of an inclined plane. If kindergarten blocks are not available, orange crates will serve the purpose or the school building steps.

8. The Wedge as an Inclined Plane (Demonstration 2-6)

Materials: Wooden door wedge; an axe; a 3 foot long, 1 by 6 inch board; and a brick.

Procedure: Using the pin board and the brick, construct an inclined plane. Compare the shape of the wooden door wedge and the axe with that of the inclined plane. How do they compare?

Discussion: The wooden door wedge and the axe are inclined planes too. They are, however, used for different purposes.



9. The Screw as an Inclined Plane (Demonstration 4-6)

Materials: A large wood screw, sheet of grey construction paper, black crayon, and a pencil.

Procedure: Cut a right triangle from a sheet of grey construction paper and draw a dark heavy line along the edge of the hypotenuse of the triangle with a black crayon as illustrated in Figure 7.5(a). Roll the paper triangle around a pencil, as shown, until the entire triangle is wrapped around the pencil. Observe what happens to the darkened edge of the triangle. Compare what you have with a large wood screw.

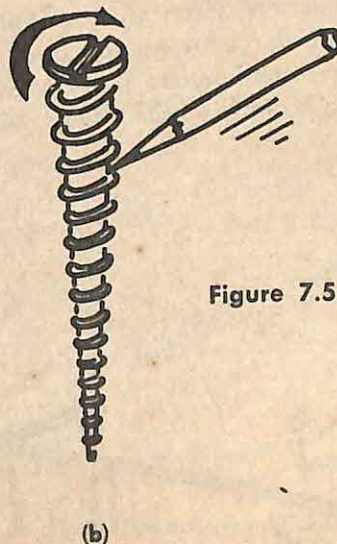
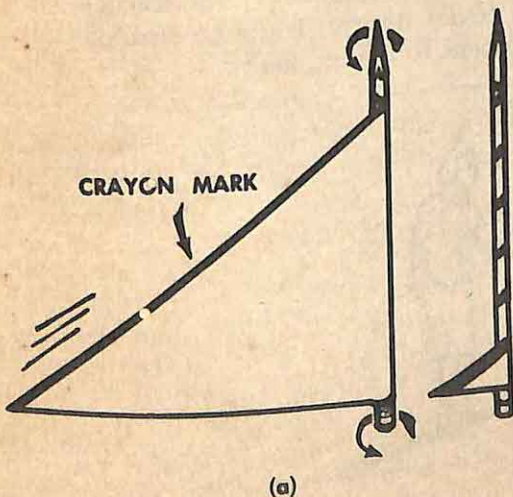


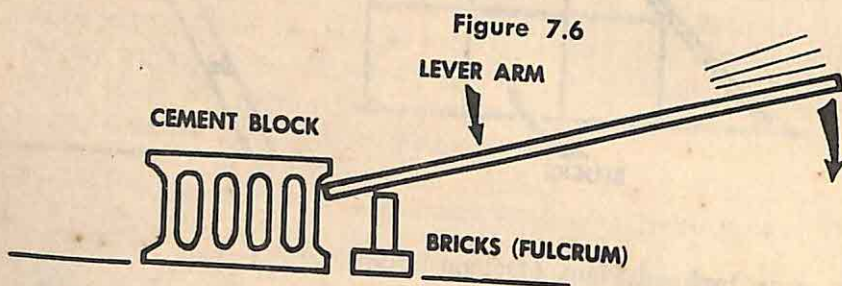
Figure 7.5

Discussion: The right triangle has the shape of an inclined plane. As it is wrapped around the pencil, it takes on the characteristics of a "barber pole" with a continuous black line wrapped around the pencil. It also takes on the characteristics of the threads of a screw. Place the tip of your pencil in the thread grooves of the screw and turn the screw. The pencil rises up a circular ramp, or *inclined plane*, as illustrated in Figure 7.5(b).

10. A Lever to Lift Heavy Weights (Demonstration and Activity K-6)

Materials: Cement block, 2 by 4 inch board 6 feet long, and two blocks of wood or bricks.

Procedure: Have one or two of the largest and strongest boys in the classroom attempt to lift one end of a cement block one inch off the floor. (Be careful that they do not strain themselves.) Then have the smallest girl in the classroom attempt to lift the same cement block with a lever as illustrated in Figure 7.6. Can she do it?



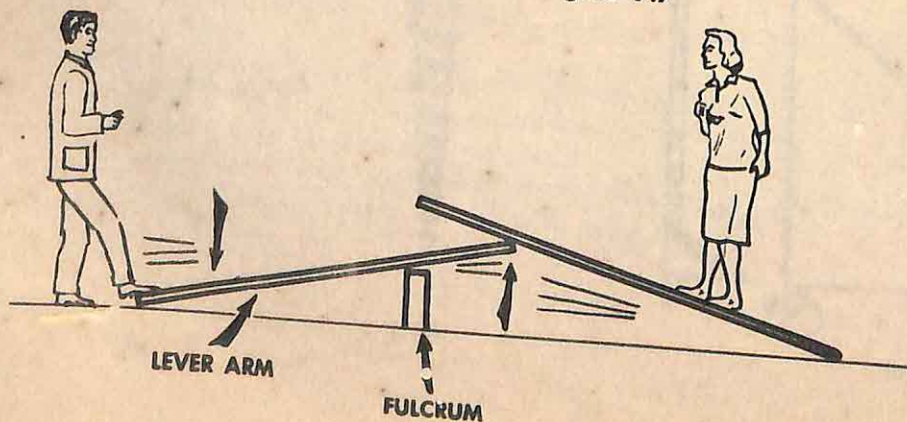
Discussion: The boys may or may not be able to lift the cement block, depending upon their age. Nevertheless, the small girl should be able to lift the cement block up several inches, using one hand or even one finger with the lever. A lever is another basic simple machine of which there are many versions and uses.

11. A Lever to Give the Teacher a Lift (Demonstration and Activity 2-6)

Materials: Two 2 by 4 inch boards 4 feet long and a block of wood.

Procedure: Arrange the equipment as illustrated in Figure 7.7. The teacher should stand on one of the boards as shown, and a student should be directed to push down on the other board. What happens to the teacher?

Figure 7.7



Discussion: The teacher is lifted several inches from the floor as the lever arm is lowered. This is one modification of the basic lever, which requires less effort to use. The fulcrum or pivot point is the block of wood.

12. A Lever to Lift a Heavy Desk (Demonstration and Activity K-6)

Materials: Two 2 by 4 inch boards one 4 feet long, one about $2\frac{1}{2}$ feet long, and a desk.

Procedure: Arrange the equipment as illustrated in Figure 7.8. Push down on the lever arm. What happens to the desk?

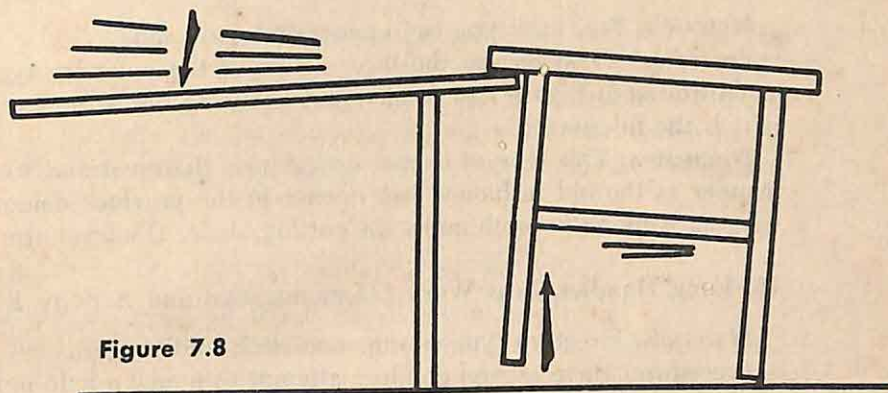


Figure 7.8

Discussion: The desk rises a few inches as the lever arm pivots on the fulcrum. This is a basic lever using a tall fulcrum.

13. Using a Screw Driver as a Lever (Demonstration and Activity K-6)

Materials: Paint can with lid and a screw driver.

Procedure: Open a paint can lid with a screw driver by placing the tip of the screw driver between the lip of the can and the lid and pushing down on the handle.

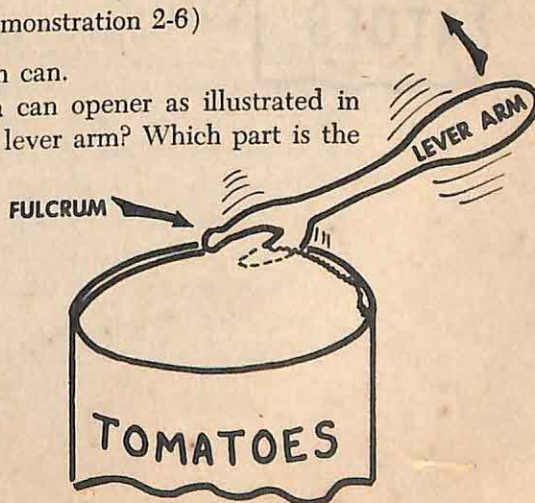
Discussion: The screw driver is the lever arm and the lip of the can is the fulcrum. As the handle of the screw driver is pushed down, the tip comes up and with it the lid.

14. Old Fashioned Can Opener as a Lever (Demonstration 2-6)

Materials: Old fashioned can opener and a tin can.

Procedure: Demonstrate the lever action of a can opener as illustrated in Figure 7.9. Which part of the can opener is the lever arm? Which part is the fulcrum?

Figure 7.9



Discussion: The handle of the can opener is the lever arm, and the metal tip above the cutting blade becomes the fulcrum as the handle is lifted up. This type of lever works when the lever arm is lifted up instead of down, as experienced in the previous activities. As the handle is lifted up, the cutting blade gets its power to cut the can.

These kinds of can openers are difficult for children to manipulate and may prove dangerous. It is recommended that the teacher demonstrate the lever action to the class.

15. Puncture Type Can Opener as a Lever (Demonstration and Activity 2-6)

Materials: Puncture type can opener and a tin can.

Procedure: Demonstrate the lever action of the puncture type can opener as illustrated in Figure 7.10. Which part of the opener is the lever arm? Which part is the fulcrum?

Discussion: This type of opener operates on the up stroke, too, in the same manner as the old fashioned can opener in the previous demonstration. The fulcrum is the little catch under the cutting blade. The lever arm is the handle.

16. Long Handles, Less Work (Demonstration and Activity K-6)

Materials: Puncture type can opener, stick, and tin can.

Procedure: Have several children attempt to punch a hole in a tin can with a puncture type can opener. This demonstration provides an ideal situation for demonstrating the effect of lengthening the lever arm of a lever. Attach a stick to the handle of a puncture type can opener as illustrated in Figure 7.11. Ask the children who previously could not use the opener because of the physical difficulty to try it again. What are the results?

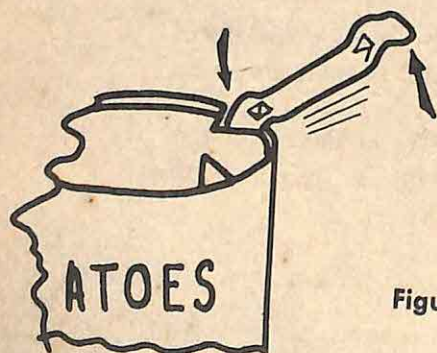


Figure 7.10

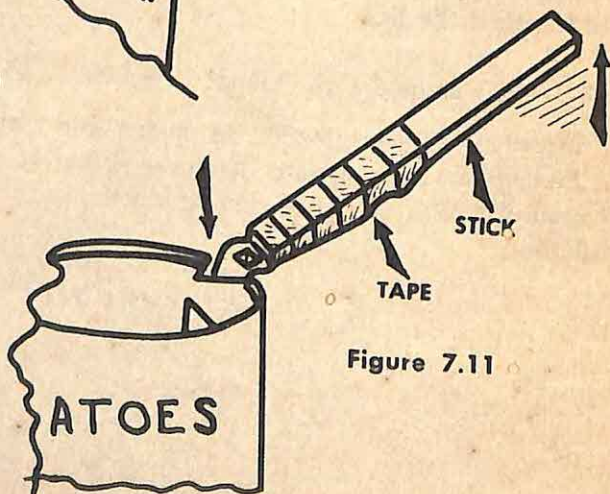
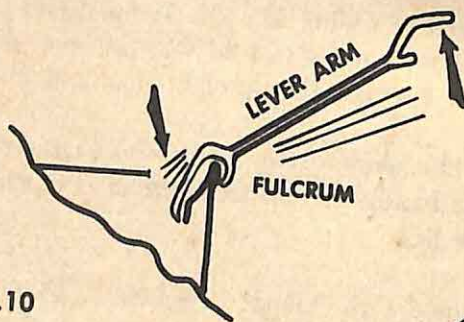


Figure 7.11

Discussion: The longer lever arm reduces the amount of force needed to do the job of puncturing the lid of the can, and the children will succeed. Try a longer arm if they don't. Most children in kindergarten, first, second and some in third grade will not be strong enough to operate the can opener without an extended lever; however, fourth, fifth, and sixth graders will have little or no trouble accomplishing the feat.

17. Longer Levers, Less Work (Demonstration and Activity K-6)

Materials: Cement block; two 2 by 4 inch boards, one $\frac{3}{4}$ feet long, the other 6 feet long; and two blocks of wood or bricks.

Procedure: Set up the equipment in the same manner as illustrated in Figure 7.6, using the 3 foot board as a lever arm. Have the children try to lift the cement block with the 3 foot lever arm. Next, use the 6 foot lever arm. Is there any difference in the amount of force required to lift the cement block?

Discussion: The 6 foot lever arm requires considerably less force to operate than the 3 foot lever arm.

18. Fun with a Lever (Demonstration and Activity K-6)

Materials: Saw horse and 2 by 6 inch board 8 feet long.

Procedure: Balance the 8 foot board on the saw horse to make a see-saw or teeter-totter. Have a heavy child sit on one end and a light child sit on the other end. What can be done to make the see-saw balance once again?

Discussion: If the heavy child moves toward the saw horse, the balance point can be reached. If the length of the board is increased on the side of the light child and shortened on the heavier child's side, the see-saw can be balanced in this way.

19. A Rotating Lever (Demonstration 4-6)

Materials: A sheet of heavy corrugated cardboard or $\frac{1}{4}$ inch thick plywood, two $\frac{1}{4}$ inch diameter dowels 3 inches long, one $\frac{1}{4}$ inch diameter dowel 8 inches long, a small cardboard box, string, and a 2 pound weight.

Procedure: Cut the cardboard or $\frac{1}{4}$ inch thick plywood into a strip 18 inches long and 2 inches wide. Drill three $\frac{1}{4}$ inch diameter holes, one at each end $\frac{1}{2}$ inch from the edge and one in the center. Insert a 3 inch dowel on each end and an 8 inch dowel in the center as illustrated in Figure 7.12(a). Mount a $\frac{1}{4}$ inch dowel 8 inches long in a box as illustrated in Figure 7.12(b), and tape the box securely to the table. This should allow the cardboard strip to rotate freely. Tie one end of a string around one of the 3 inch dowels mounted on the cardboard strip and tie a weight to the other end. Rotate the strip of cardboard and observe what happens to the string and weight.

Discussion: The device constructed is a rotating lever which, however, does not produce a mechanical advantage because it does not reduce the effort needed to lift the weight. As one end is rotated down, the other end comes up. As the end with the string attached comes up, the string and weight move up too. As the lever is rotated further, the second dowel lifts the weight even higher, and the string becomes shorter.

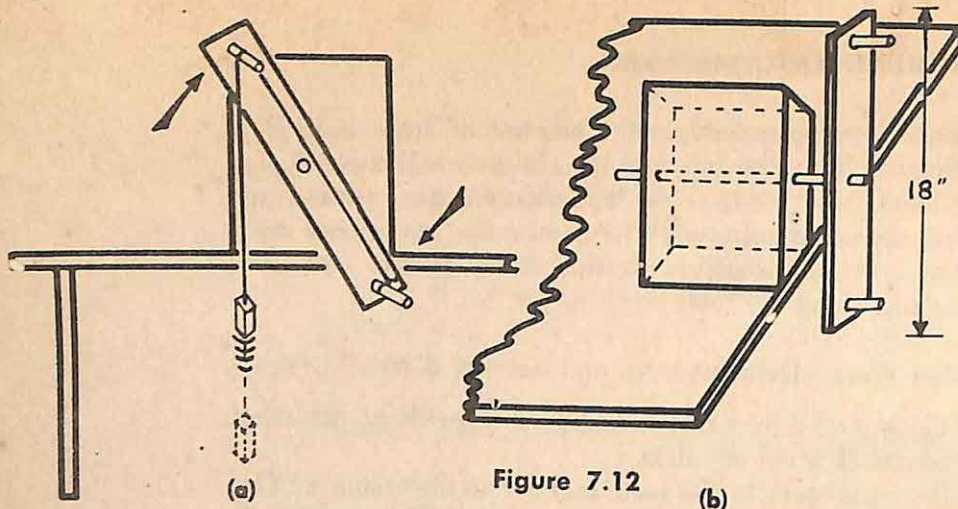


Figure 7.12

(b)

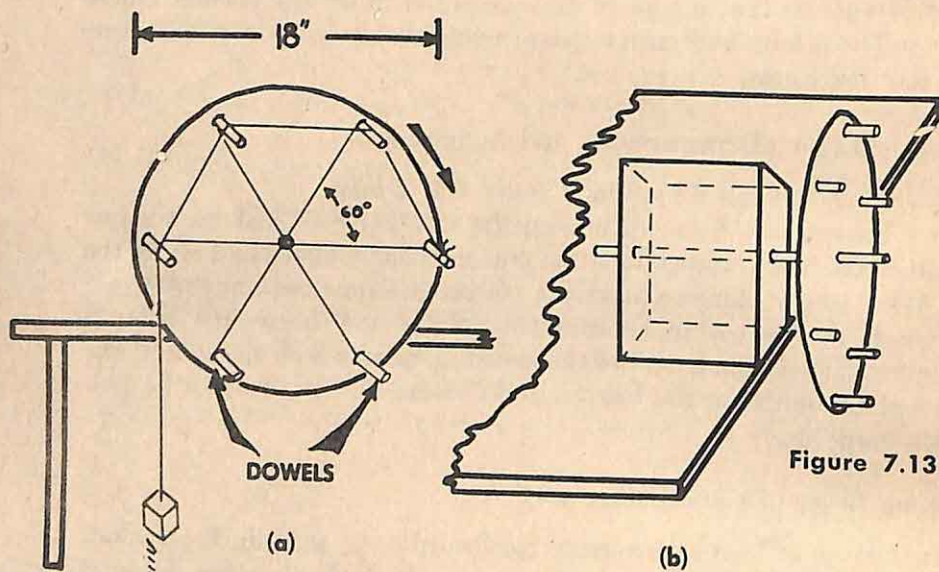


Figure 7.13

20. A Wheel as a Lever (Demonstration 4-6)

Materials: Sheet of heavy corrugated cardboard or $\frac{1}{4}$ inch thick plywood, small cardboard box, six $\frac{1}{4}$ inch diameter dowels 3 inches long, one $\frac{1}{4}$ inch dowel 8 inches long, string, and a weight.

Procedure: Cut out a disk 18 inches in diameter from heavy corrugated cardboard or $\frac{1}{4}$ inch plywood. Drill six $\frac{1}{4}$ inch holes 60 degrees apart and $\frac{1}{2}$ inch from the edge of the disk and insert a 3 inch dowel in each hole as illustrated in Figure 7.13(a). Drill another $\frac{1}{4}$ inch hole in the center of the disk and insert a $\frac{1}{4}$ inch dowel 8 inches long for an axle. Mount the axle and wheel in a box as illustrated in Figure 7.13(b), and tape the box securely to the table. The wheel should be able to turn freely. Tie one end of a string around one of the 3 inch dowels and tie a weight to the other end. Turn the wheel and observe what happens to the string and weight.

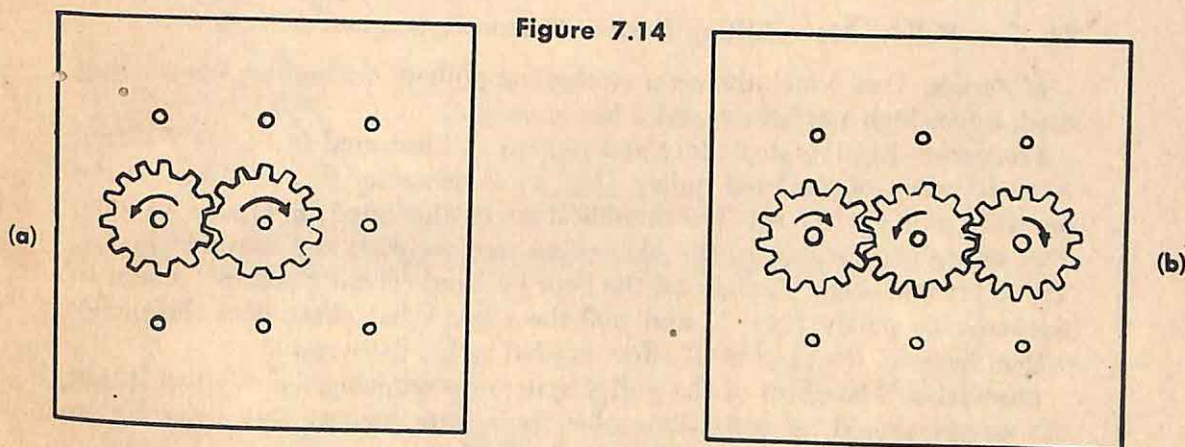
Discussion: The device constructed in this demonstration is similar in de-

sign to the rotating lever in Demonstration 17 of this section—with a few exceptions. In this demonstration we actually have 3 rotating levers mounted on a disk. As the disk turns, each lever pulls the weight up a little higher until the string is wrapped in a hexagonal figure around the dowels. If we were to add a dowel in between each existing dowel, we would have 6 rotating levers, and the figure made by the string would be a 12 sided one. It would look more like a circle than the hexagonal figure. If we placed another dowel between each of these twelve dowels, we would have a 24 sided figure which would look even more like a circle than the twelve sided figure. If we kept adding more and more dowels, we would eventually have a nearly round figure that looked very much like a wheel. We can think of a wheel, then, as a rotating lever. A good example of a very useful rotating wheel lever is a pulley. A single pulley does not produce a mechanical advantage. It reduces friction on the rope but does not reduce the effort needed to lift the weight.

21. Gears as Special Wheels (Demonstration 2-6)

Materials: Plastic toy gear set.

Procedure: Set up two gear wheels on the plastic gear set as illustrated in Figure 7.14(a). Turn one gear by hand. In which direction does the other gear turn. Set up three gear wheels as illustrated in Figure 7.14(b). Turn one of the end gears by hand. In which direction do the other two gears turn?



Discussion: If two gears are used, the drive gear (the one with the turning power) will turn the other gear in the opposite direction. We can use gears, then, to change the direction of rotary motion. With three gears meshed together, we can accomplish two things: we can turn one gear in the opposite direction of the drive gear and the other one in the same direction as the drive gear. Can you think of some practical application of these gears?

22. The Pulley; A Specialized Wheel (Demonstration 2-6)

Materials: One 5 inch diameter clothesline pulley, clothesline, a weight, two tables or two desks, and a broomstick.

Procedure: Display the pulley, emphasizing the groove in the wheel in which the rope rides. Tie the pulley to a broom handle and suspend the broom handle between two tables as illustrated in Figure 7.15. Run a rope through the pulley and tie a weight on one end as shown. Mark one of the spokes of the pulley with a piece of tape and observe its motion as you pull the other end of the rope.

Discussion: As the rope is pulled, the pulley turns and the marked spoke rotates with it. As the pulley turns, the rope is drawn up and the weight is lifted from the floor. Again we can see that a wheel (pulley) is a rotating lever.

23. Pulling with a Pulley (Demonstration and Activity 2-6)

Materials: One 5 inch diameter clothesline pulley, clothesline, and a toy wagon.

Procedure: Tie the pulley to the leg of a heavy table as illustrated in Figure 7.16. Run a rope through the pulley groove and tie one end to the axle of a toy wagon as shown. Have a student sit in the wagon and pull on the other end of the rope. In which direction does the wagon travel?

Discussion: The wagon will move in the opposite direction in which the rope is being pulled—it will move toward the pulley. We see, then, that a pulley can be used to change the direction of the applied force.

24. Two Pulleys Make Lifting Easier (Demonstration and Activity 3-6)

Materials: Two 5 inch diameter clothesline pulleys, clothesline, some strong cord, 6 foot high stepladder, and a heavy weight.

Procedure: Rig the stepladder and pulleys as illustrated in Figure 7.17(a). A modification of the fixed pulley (No. 1) is necessary to accommodate the movable pulley (No. 2). This modification is illustrated in Figure 7.17(b). The strong cord is tied to the clothesline that supports the movable pulley. Try to lift the weight straight off the floor by hand. Then attach the weight to the movable pulley (No. 2) and pull the cord. What effect does the pulley system have on the amount of effort needed to lift the weight?

Discussion: The effect of the pulley system on reducing the effort of lifting the weight should be quite noticeable. In a later activity this reduction in effort or work will be measured and compared.

B. A QUANTITATIVE STUDY OF SIMPLE MACHINES

1. The Advantage of a Lever (Demonstration and Activity 4-6)

Materials: A 2 by 4 inch board 6 feet long, a block of wood, a 10 pound weight (a sand bag works well), a spring scale, and table.

Procedure: Find the center of the board and mark it with a crayon. Place the board (lever arm) on the table with the center mark over the block of wood (fulcrum). Place the 10 pound weight on one end of the board and

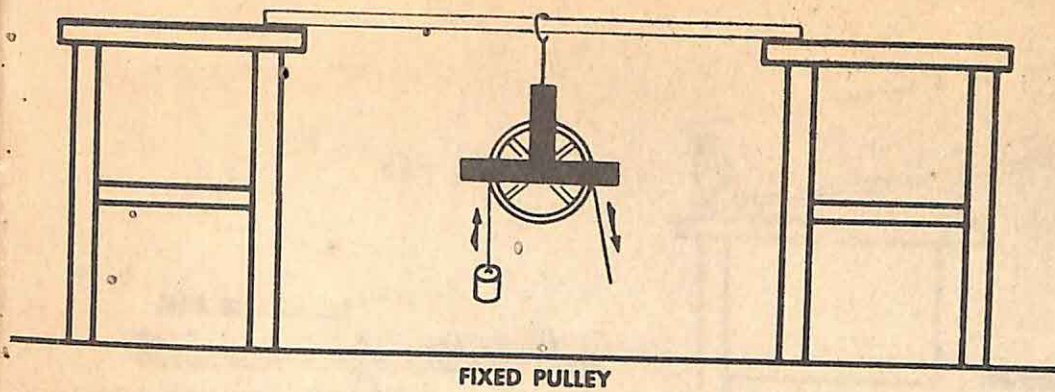


Figure 7.15

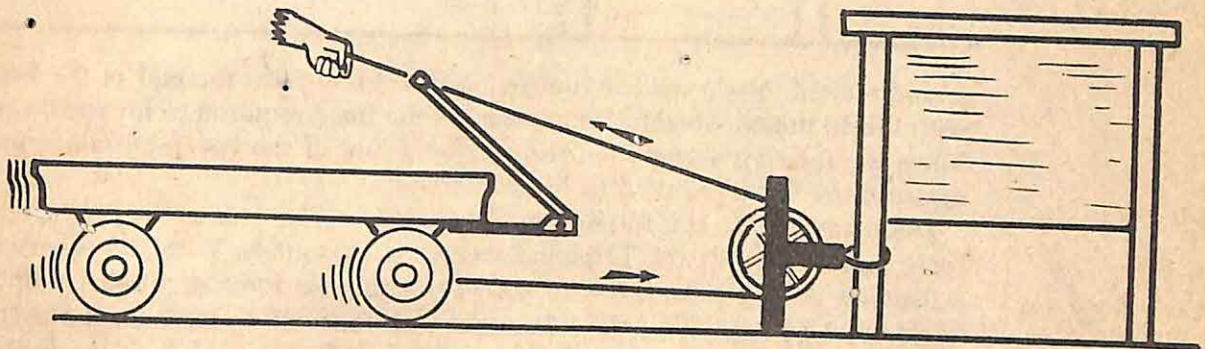
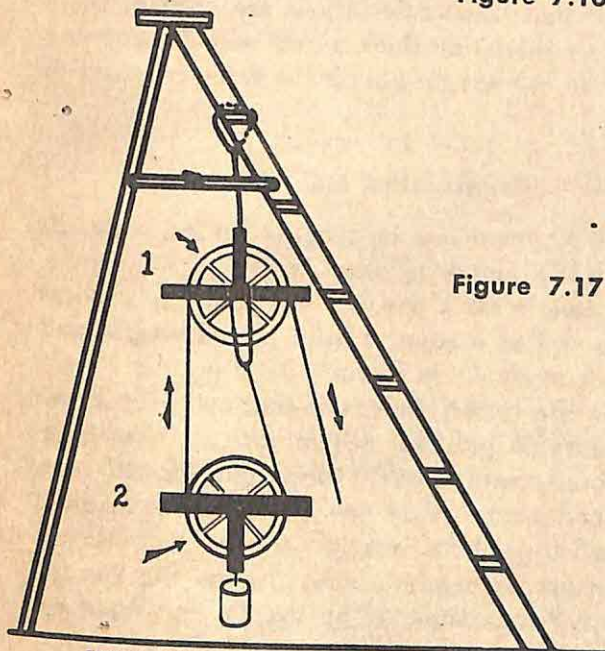


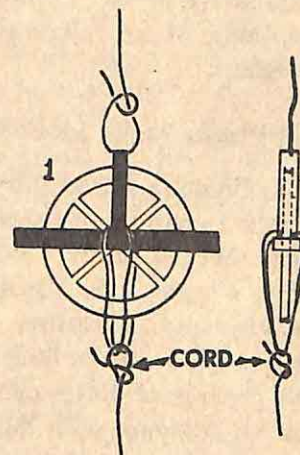
Figure 7.16



FIXED AND MOVABLE PULLEYS

(a)

Figure 7.17



FIXED PULLEY (NO. 1)

(b)

allow the other end to extend over the edge of the table as illustrated in Figure 7.18. Attach the spring scale to the end of the board and pull down on it. Observe and record the amount of force in pounds required to lift the 10

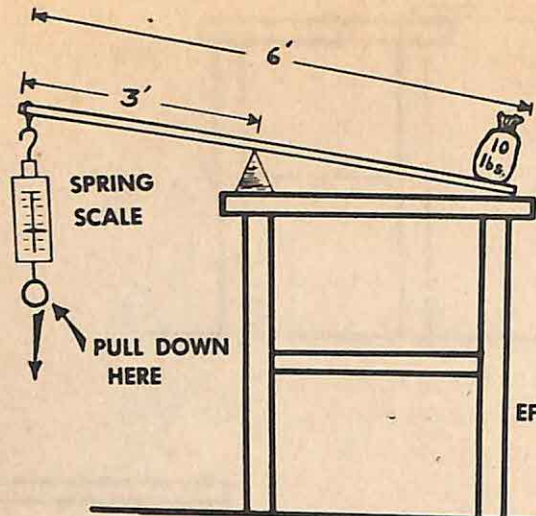
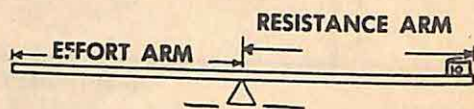


Figure 7.18



$$\text{EFFORT} \times \text{EFFORT ARM} = \text{RESISTANCE} \times \text{RESISTANCE ARM}$$

$$E \times E \text{ ARM} = R \times R \text{ ARM}$$

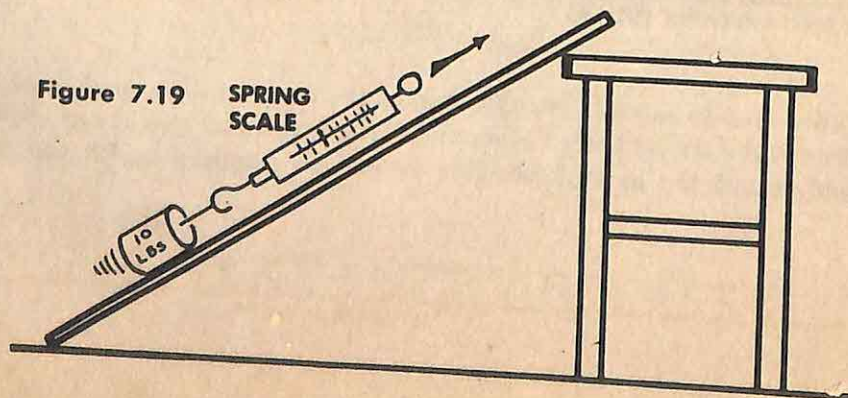
pound weight. Move the fulcrum to a point 2 feet from the end of the board with the 10 pound weight. Again measure the force required to lift the weight. Move the fulcrum 4 feet from the weighted end of the board and once more measure the force required to lift the weight.

Discussion: With the fulcrum in the middle of the board (lever arm), the force required to lift the 10 pound weight is 10 pounds. With the fulcrum at a distance of 2 feet from the 10 pound weight, the force required to lift the weight is 5 pounds. With the fulcrum at a distance of 4 feet from the weight, the force required to lift the weight is 20 pounds. If you follow the formula shown in Figure 7.18, you will find that these calculations are correct. Have the children arrive at this formula by recording their results and determining how the distance of the fulcrum from the weight affects the force required to lift the weight.

2. Inclined Planes Make Less Work (Demonstration and Activity 4-6)

Materials: Wooden board 1 by 6 inches 6 feet long, table, spring scale, 10 pound weight (a sand bag works well), and a length of rope.

Procedure: Set up an inclined plane with a wooden board and a table as illustrated in Figure 7.19. Tie one end of a rope to a 10 pound weight and attach the other end to a spring scale as shown in Figure 7.19. Drag the weight up the incline plane by pulling on the spring scale. Observe and record the number of pounds of force necessary to pull the weight up onto the table. How does this compare with the force required to lift the weight directly onto the table without using the inclined plane? Vary the angle of the inclined plane and record the force required to pull the weight up onto the table for each angle you choose. Record your observations and discuss the results. Make a graph of the relationship between angle of inclination and force required to move the weight.



Discussion: The effort required to pull the 10 pound weight up the inclined plane will be less than the 10 pounds of effort required to lift it directly onto the table. As the angle of incline is increased, the force required to pull the weight up the incline will also increase. As the angle of incline decreases, so will the force required to pull the weight.

3. The Advantages of Using Pulleys (Demonstration and Activity 4-6)

Materials: Six 5 inch diameter clothesline pulleys, clothesline, 10 pound weight, two tables or desks, broomstick, and two stepladders.

Procedure: Set up a single pulley system as illustrated in Figure 7.15 of Section A. Set up a double pulley system as illustrated in Figure 7.17 of Section A. Set up a single pulley system as illustrated in Figure 7.20. Attach the 10 pound weight to each pulley system and read from a spring scale attached to the pulling rope of each system the force required to lift the weight. Record your findings. What can you determine from these readings?

Discussion: The force required to lift the 10 pound weight with a fixed single pulley system is 10 pounds. For a two pulley system, one fixed and one movable, the force required is a little more than 5 pounds. (Theoretically, it should be $\frac{1}{2}$ the weight, exactly 5 pounds, but this does not account for friction in the system.) The force required to lift the 10 pound weight with a single movable pulley system is the same as that required by the double pulley system, which had one fixed and one movable pulley. The reason for this can be explained by a very simple and easy-to-remember rule. *Count the number of ropes that actually support the load.* In the first system (Figure 7.15) we have one rope supporting the load. In the second system (Figure 7.17) we have two ropes supporting the load. In the third system we again (Figure 7.20) have two ropes supporting the load. In conjunction with measuring the mechanical advantage of each pulley system, also investigate the distance the rope must be pulled to lift the weight a given height in each system. Is there any difference?

4. Measuring Gear Ratios (Demonstration and Activity 4-6)

Materials: Sheets of heavy corrugated cardboard, single edge razor blade, drawing compass, two flat headed roofing nails, string, yardstick, sheet of paper 24 inches long and 6 inches wide, and a bicycle.

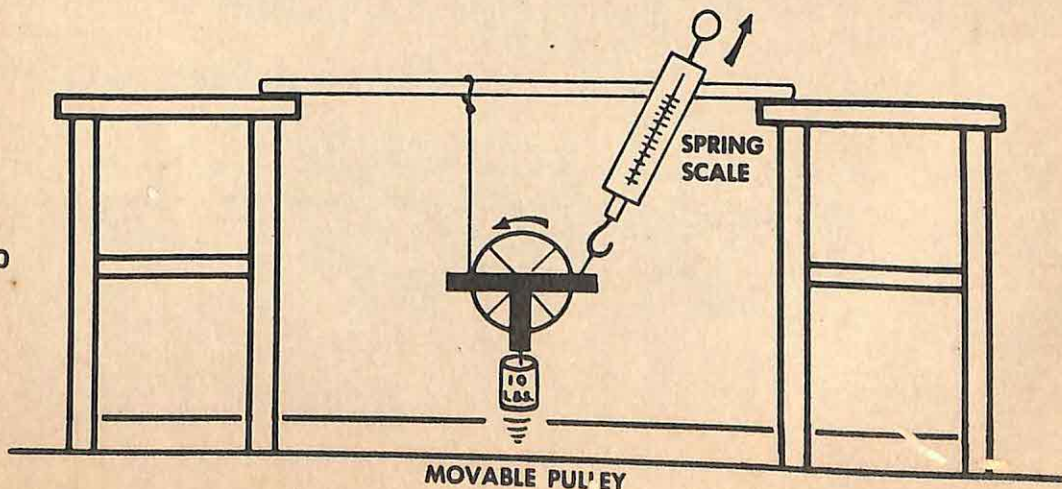


Figure 7.20

Procedure: Cut out a disk 3 inches in diameter and another disk 6 inches in diameter from heavy corrugated cardboard. Mount both disks on a sheet of heavy corrugated cardboard with a flat headed roofing nail in the center of each disk so that the disks touch each other. Mark the disks with a crayon at the point where they touch each other. Rotate the larger disk slowly and record the number of times the smaller disk turns before the large disk makes one revolution and the marks on each disk line up with each other again. Measure the circumference of each disk by surrounding it with a length of string and then laying the string out along the edge of a ruler. Compare the diameter of the two disks and record your results. Compare the diameter of the small and large sprocket gear wheels on a bicycle. Compare the number of teeth on each sprocket gear. Record your results.

Discussion: The smaller disk (3 inch diameter) will make two rotations to one of the large disk (6 inch diameter). This may be referred to as a *ratio* of two turns to one. The circumference of the smaller disk is about $9\frac{1}{2}$ inches, and that of the larger disk is about 19 inches. The diameters and the circumferences are both at a two to one ratio. Knowing the circumferences or the diameters of both disks will tell us the number of turns one disk will make when driven by another. In this case it was two turns of the small disk to one of the large disk. Gear ratios can be measured in the same manner. Another way to determine the gear ratio of two meshing gears is by counting the number of teeth on each gear and comparing the two numbers. The average gear ratio for bicycles is two to one. This means that for every turn of the large drive sprocket the back wheel sprocket will turn twice. How could you increase the speed of your bicycle and still turn the drive sprocket the same number of revolutions?

VIII



The Study of Light

Light is a form of energy which is constantly under study by scientists, but its causes are not thoroughly understood. We already know from our study of plants that light plays a major role in the production of food and materials for clothing, which are essential to our survival on earth.

The "magic" of our sense of sight is wholly dependent on light—reflected light and direct light whether it be sunlight or man-made light of various origins.

Although a thorough understanding of the cause of light is not known, many of its characteristics are known. Chapter VIII deals mainly with the study of the characteristics of light, beginning with very simple demonstrations and activities involving the basic characteristics of light, reflection, and refraction. Many of these demonstrations and activities are games from which much can be learned about light.

Section C, "Working With Light," emphasizes a more scientific approach to the study of the characteristics of light and its practical application in various devices, such as telescopes and cameras.

A. THE SIMPLE FACTS ABOUT LIGHT

1. The Light We See (Demonstration K-6)

Materials: Flashlight or slide projector.

Procedure: When can you see light? Shine the light source directly at the children in the classroom. Can you see the light now? Turn the light source away from the children (more than 90 degrees) and shine it on the floor behind a desk or cabinet or out the open door or window where the reflected light cannot be seen. Can you see the light now? Shine the light onto the

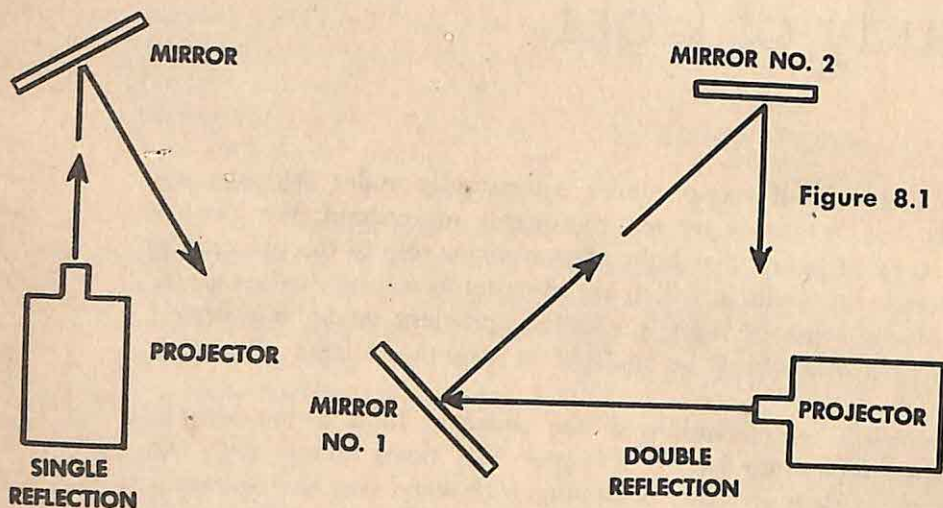
wall or ceiling with the light source still directed 90 degrees or more away from the children. Can you see the light now?

Discussion: The light can only be seen in this demonstration when the source of the light is directed at the students or is reflected from an object which can be seen.

2. Reflecting Light with Mirrors (Demonstration and Activity K-6)

Materials: Light source (projector or flashlight) and two pocket mirrors.

Procedure: Direct a beam of light in a direction 90 degrees away from the audience. Have a student with a mirror in hand stand directly in line with the light beam. What can the audience see? Figure 8.1 suggests a way which can be used to reveal the source of light to the class using two mirrors. Why does this work?



Discussion: The single mirror can be made to reflect the light from the light source directly at the audience. If two students each hold mirrors, the light can be reflected twice—first from one mirror then from the other. Here, it is the second reflection which the audience sees. The two students, however, must be standing where they will be able to intercept the light beam with their mirrors. Can you think why?

3. Other Materials Reflect Light Too (Demonstration K-6)

Materials: Metal pie tin, water, white paper, gray paper, black paper, wood, and a flashlight.

Procedure: Darken the classroom as well as you can before beginning this demonstration. Direct the beam of light from a flashlight onto the various materials listed above. Can you see them? Is the reflected light from all the materials of the same brightness?

Discussion: Light is reflected from all the materials. They are visible because they all reflect light—yes, even the black paper. Any material which can be seen by the eye does reflect light. Some objects and materials such as mir-

rors, shiny pans, white paper and water reflect more light than other materials because they have very smooth surfaces and are light in color. The gray and black papers reflect less light because of their darker colors. Rough surface materials reflect less light than do smooth surfaces.

4. Light Travels in a Straight Line (Demonstration and Activity K-6)

Materials: Flashlight with a narrow beam of light, sheet of black construction paper, and tape.

Procedure: Tape a shield of black construction paper around the end of a flashlight as illustrated in Figure 8.2. Mount the flashlight on a cardboard box as shown and place it on a desk. Have a student stand directly in front of the flashlight so he can see the light. Mark this spot on the floor with a piece of tape. Have the child move slowly either to the left or to the right and report when he or she no longer sees the source of the light. Mark this spot on the floor with a piece of tape. Have the student move toward the original position in front of the light and report when the source of the light is seen again. Now rotate the box to the left or right and have the student report when he or she loses sight of the light source. Stop the rotation of the box and have the student move to a position where the light source can be seen. Where is the student in relation to the flashlight when the beam of light can be seen?

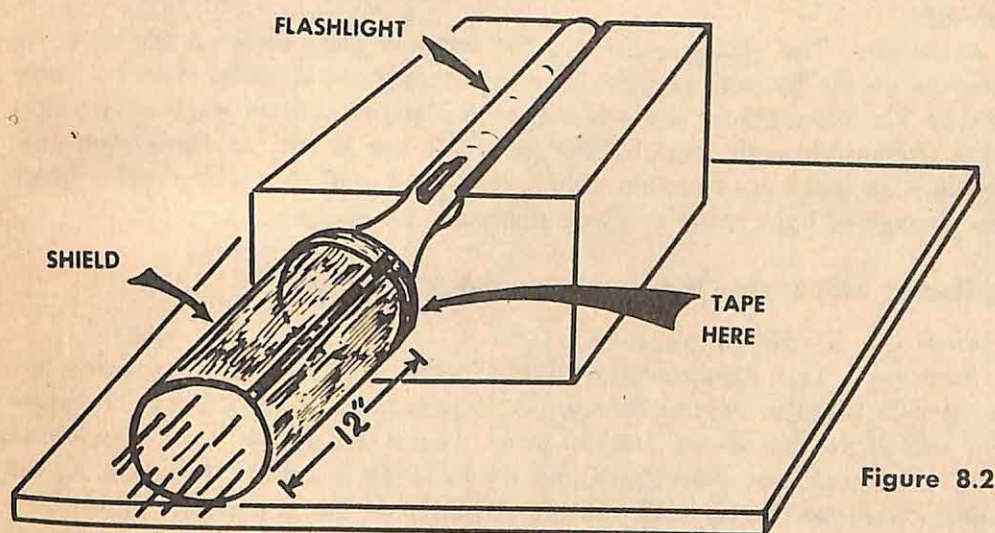


Figure 8.2

Discussion: The child must be almost directly in front of the flashlight in order to see the beam of light. The word "almost" is used because there will be a slight discrepancy due to the width of the beam of light. For all practical purposes, however, the student can only see the source of light when he or she is standing directly in front of it. This is due to the fact that under normal circumstances light travels in a straight line. Scientists have proven that light does travel in a curved line over great distances, and this fact should be mentioned.

5. Light Carries Heat (Demonstration and Activity 2-6)

Materials: Magnifying glass and a sheet of paper.

Procedure: With a magnifying glass, focus the rays of the sun on a piece of paper to the smallest concentration of light possible. What happens?

Discussion: A magnifying glass is a convex lens which bends the light rays toward a point, called the focal point. This is the spot at which the sun's rays appear most intense on the paper. This is the spot where all the sun's light rays which passed through the lens were brought together in a very tightly concentrated bundle. The heat carried by the sunlight is also concentrated at this small spot, causing the paper to burn after a certain period of time.

6. Transparent, Translucent and Opaque Materials (Demonstration and Activity 2-6)

Materials: Flashlight, clear sheet of plastic, window glass, tissue paper, sheet of white notebook paper, sheet of black construction paper, pine board 1 by 6 by 6 inches, and a sheet of rubber from an inner tube.

Procedure: Hold each piece of material snugly against the face of the flashlight, one at a time. Through which materials can the light pass? Which materials restrict the passage of light or prevent any of the light from passing through?

Discussion: The clear plastic and the window glass have no apparent restriction on the passage of light. These materials are considered to be *transparent*. The tissue paper and white notebook paper prevent some of the light from passing through them. These materials are known as *translucent* materials. The black construction paper, the wood, and the rubber sheet block the passage of light entirely. These materials are *opaque*.

7. Racing with Light (Demonstration and Activity K-6)

Materials: Flashlight and a ball.

Procedure: This demonstration is conducted as a race. Two students line up at a starting line next to the teacher, who is holding a flashlight. The finish line will be the blackboard ten feet away. At the signal "Go," the two students will race toward the blackboard and try to touch it with their hands. At the signal "Go," the teacher will aim the flashlight at the blackboard and switch it on. Who wins: the light or the students? Move the starting line closer and closer to the blackboard. Who wins this time? Next, have one of the better ball throwers in the classroom step up to the starting line with a ball in his hand. At the signal "Go," have the student throw the ball at the blackboard as fast as he can. At the same time, at the signal "Go," the teacher will aim the flashlight at the blackboard and switch on the light. Who wins this time, the ball or the beam of light? Move the starting line closer and try again.

Discussion: The beam of light, of course, will reach the blackboard first. Throwing a ball is faster than running but still much slower than the speed of light. Light travels faster than any car, jet plane, or rocket made by man. Light is estimated to travel at about 186,000 miles per second.

B. FUN WITH PLANE MIRRORS

1. Seeing Behind You (Activity K-6)

Materials: Pocket mirror.

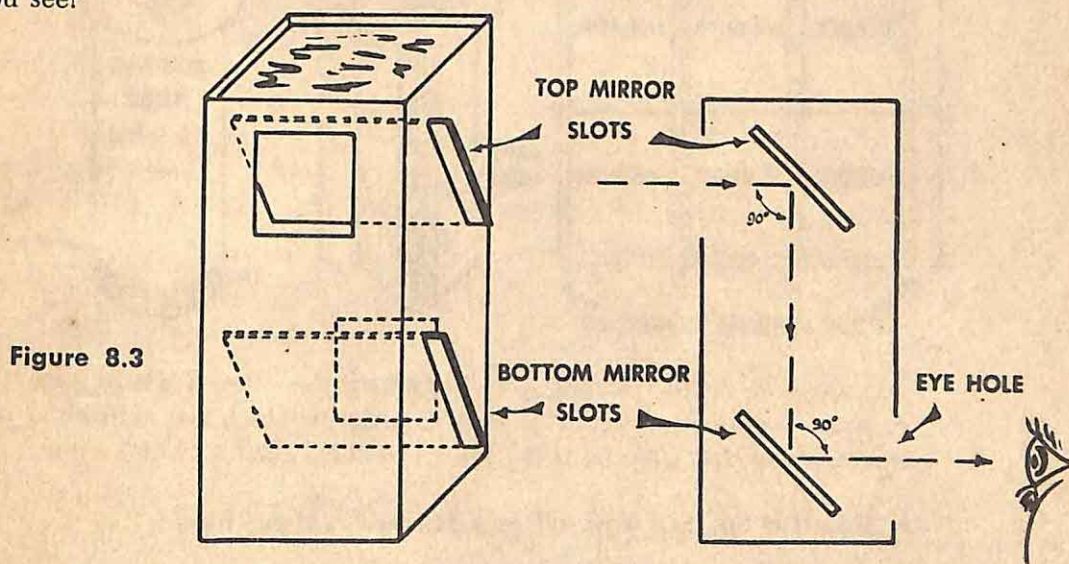
Procedure: Hold a mirror up to one of your eyes at a distance of about six inches. Tilt the mirror so that you can see the reflection of objects behind you.

Discussion: The images of the objects behind you are reflected to your eye by the mirror.

2. Making a Periscope (Activity 2-6)

Materials: Cardboard milk carton and one double pocket mirror 2 by 3 inches.

Procedure: Separate the double pocket mirror carefully with a knife blade to make two single mirrors. Construct a periscope as illustrated in Figure 8.3. Cut a slot at a 45 degree angle on each of two sides of the milk carton and slide the mirrors in. Allow the mirrors to extend over the outside edge of each slot to hold them in place. Bring the eye hole up to your eye as shown. What do you see?



Discussion: The reflected light rays from an object strike the top mirror, which in turn reflects them 90 degrees to the bottom mirror. The bottom mirror reflects the same light rays another 90 degrees to the eye.

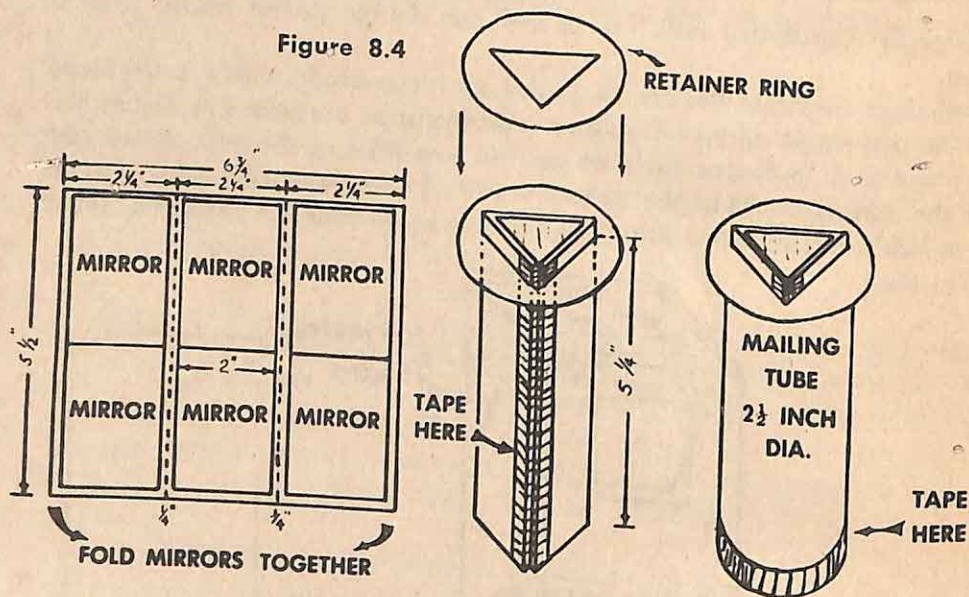
3. Making a Kaleidoscope (Activity 2-6)

Materials: Six single pocket size mirrors 2 by 3 inches, mailing tube, sheet of cardboard, glue or rubber cement, tracing paper, tape, and small bits of colored paper.

Procedure: Cut out a sheet of cardboard 6 by $6\frac{3}{4}$ inches. Glue six 2 by 3 inch pocket mirrors to this board as illustrated in Figure 8.4(a). Leave about

$\frac{1}{4}$ inch clearance between each mirror and $\frac{1}{8}$ inch clearance on each outer border as shown. Bend the cardboard at the dotted line labeled fold so that a triangular object is formed with the six mirrors on the inside. Tape the triangular object together as illustrated in Figure 8.4(b). Tape a sheet of tracing paper, copy paper, or waxed paper over one end of a $5\frac{1}{2}$ inch long mailing tube as illustrated in Figure 8.4(c). Insert the triangular object into the mailing tube as shown and push the retainer ring snugly against the open end of the mailing tube. This will leave about $\frac{1}{2}$ inch section of the triangular object projecting out above the retainer ring. This is the eye piece. Hold the mailing tube vertically and drop several bits of colored construction paper into the triangular object. Hold the translucent end of the mailing tube to your eye, downward angle over a light source. Rotate the mailing tube in your hand. What do you observe?

Figure 8.4



Discussion: As the mailing tube is rotated, the colored bits of paper change position, producing colorful geometric patterns which are multiplied by their reflections in the mirrored tube. This device is called a *kaleidoscope*.

4. How Do You See Yourself in a Mirror (Activity K-6)

Materials: Mirror 12 by 12 inches.

Procedure: Stand before a mirror and look at your reflection. Bring your right hand up to your right eye. What does your reflection do? Wink your left eye. What does your reflection do?

Discussion: When you bring your right hand up to your right eye, your reflection in the mirror brings his left hand up to his left eye. When you wink your left eye, your reflection in the mirror winks his right eye. Mirrors reverse the images they reflect. To understand this better, have two students stand facing each other on either side of a table. Have one student raise his left

hand. Have the other student raise that hand which is directly across from the one raised by the first student. This hand will have to be his right hand, just as in the mirror.

5. What Happens to the Written Word in a Mirror? (Demonstration and Activity 4-6)

Materials: Mirror 12 by 12 inches, sheet of white paper, and a black crayon.

Procedure: Lay a sheet of plain white paper flat on a table top with one edge up against the bottom edge of a mirror as illustrated in Figure 8.5. Write a word on the paper in front of the mirror. How do the letters of the word appear in the mirror as you write them?

Discussion: The word reflected from the mirror is upside down and reversed. The next demonstration will tell you why.

6. "U" in the Mirror (Demonstration and Activity 4-6)

Materials: Sheet of black construction paper, scissors, and a 12 by 12 inch mirror.

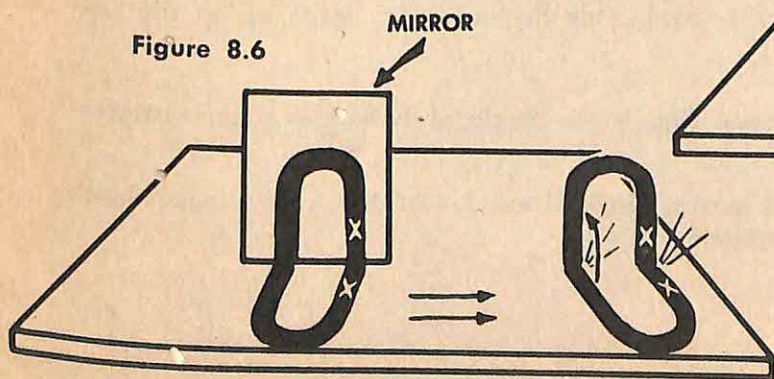
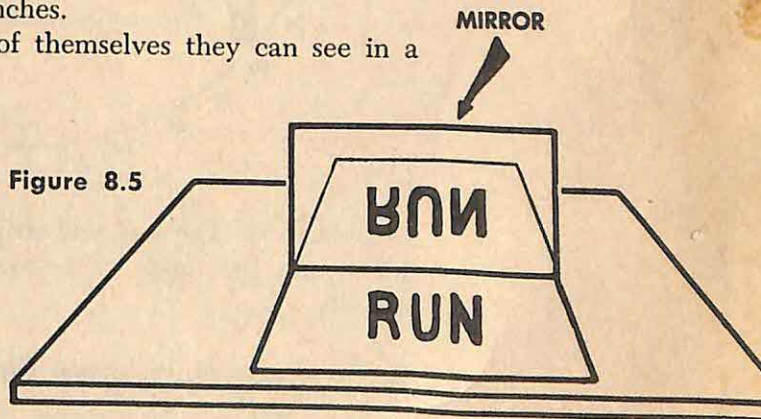
Procedure: Fold the sheet of black construction paper in half and cut out a large letter "U." Hold the letter "U" flat on a table top with the open end of the "U" at the bottom edge of the mirror as illustrated in Figure 8.6. Mark an "X" on the right side of the letter with white chalk. What happens to the letter "U"?

Discussion: The "U" is upside down and the open ends of the real letter and the reflection together form an oval. The letter "U" in the mirror is reversed, with the "X" on the left side instead of the right side. To get a better idea of why the letter is reflected like this, slide the letter "U" from in front of the mirror to one side. Unfold the double letter slowly as illustrated in Figure 8.6. Now do you see why?

7. How Much Can You See of Yourself in a Mirror? (Activity 4-6)

Materials: Mirror about 12 inches by 12 inches.

Procedure: Ask your students how much of themselves they can see in a



plane mirror. Hold a mirror at a distance of a foot or two in front of a student so that the top of his head is just at the top of the mirror. Have the student place his hand at the lowest position of his body that he can see in the mirror. Now have him step back from the mirror several feet. How much, more or less, can he see of himself? Do not move the mirror up or down.

Discussion: No matter how far the student moves, he will see no more or no less of himself, which may surprise many of your students and even yourself.

C. WORKING WITH LIGHT

1. The Angle of Hit Equals the Angle of Bounce (Demonstration 5-6)

Materials: Large sheet of paper 48 inches by 48 inches, large rubber ball 5 inches in diameter, and a tin can.

Procedure: Draw a large protractor on a sheet of paper as shown in Figure 8.7 and place it on the floor against the wall in your classroom. Set a tin can at any angle position on one half of the protractor. Roll the rubber ball across the same angle position on the other half of the protractor, aiming it toward the center of the protractor as illustrated in Figure 8.7.

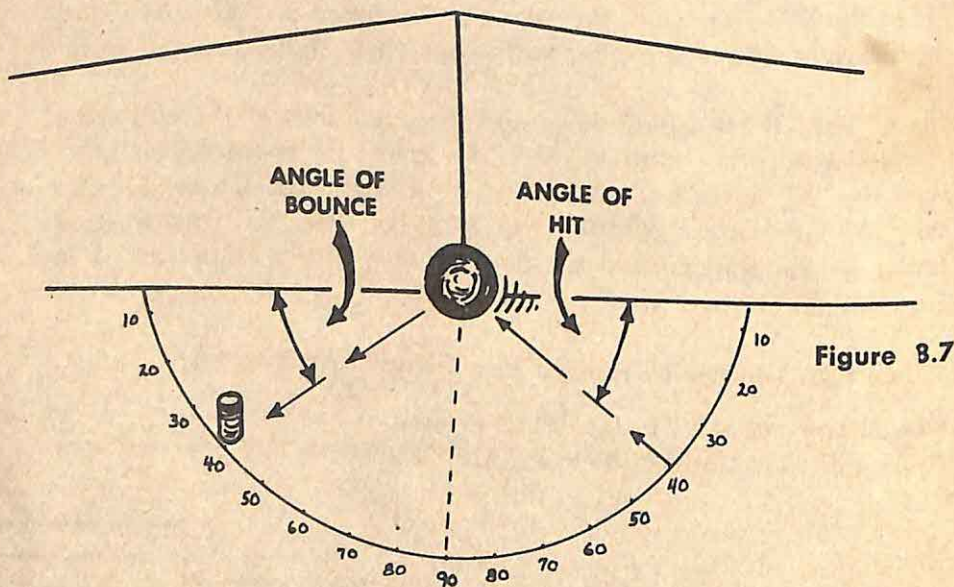


Figure 8.7

Discussion: The ball will strike the tin can, knocking it over. The angle of hit equals the angle of bounce. This demonstration leads up to the next activity.

2. The Angle of Incidence Equals the Angle of Reflection (Demonstration and Activity 5-6)

Materials: Pocket size mirror, block of wood, two pins, rubber band, black crayon, and a small protractor.

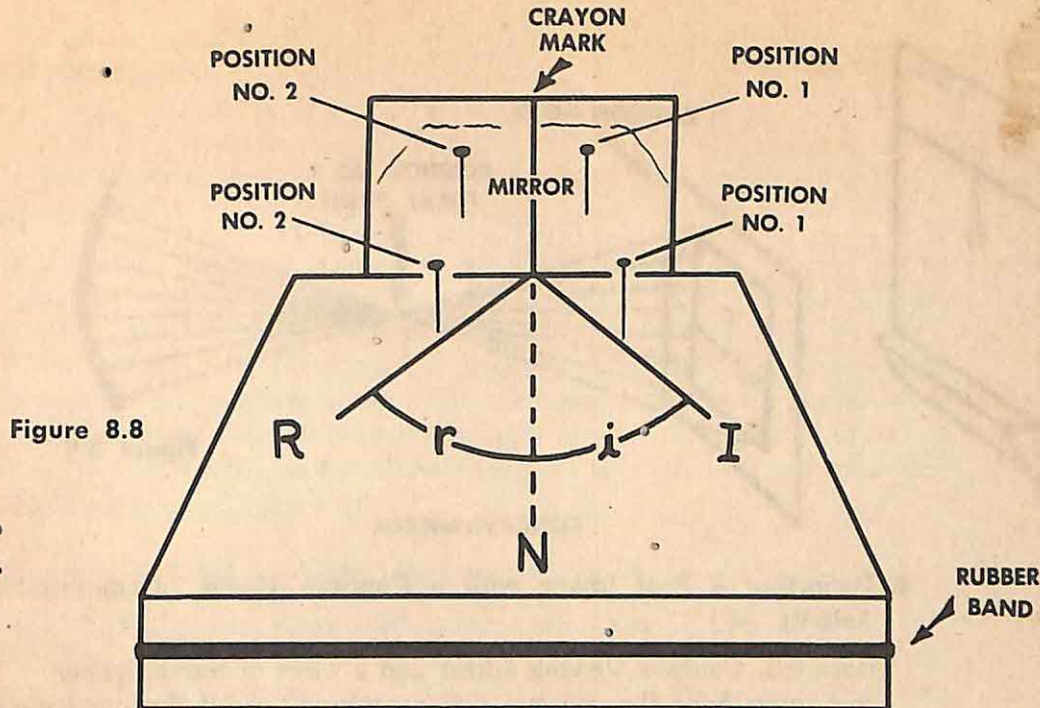


Figure 8.8

Procedure: Draw a line across the center of the mirror with a crayon or scratch a line on the mirror with a nail. Using a rubber band, attach the mirror to the block of wood as illustrated in Figure 8.8. Draw a line on the block of wood perpendicular to the center line of the mirror as shown and label it "N." This is the *normal angle*, 90 degrees or a right angle. Stick pin No. 1 into the block of wood at about a 45 degree angle from the mirror. Stick pin No. 2 into the block of wood so that it lines up with the reflection of pin No. 1 and the center line of the mirror as shown. Now draw a line from the center line on the mirror to each pin. Measure the angle between line "N" and line "I" and between line "N" and line "R." Label these angles as indicated in Figure 8.8.

Discussion: Angle "i" will be equal to angle "r." The angle of incidence "i" is equal to the angle of reflection "r." This is the same as the angle of hit equaling the angle of bounce in the previous demonstration.

3. Concave Mirrors (Activity 5-6)

Materials: Shaving (concave) mirror.

Procedure: Have a student hold a concave shaving mirror close to the face of one of his classmates. A concave mirror is one in which the reflecting side curves away from you. What does the student observe about his reflection? Have the person looking into the shaving mirror move slowly away from his classmate holding the mirror and report to the class what he observes happening to his reflection.

Discussion: When the student's face is close to the mirror, it appears to be magnified. As he moves away from the mirror, the reflection becomes more and more distorted and finally appears smaller, upside down, and reversed in the mirror. The next activity will help you to understand why.

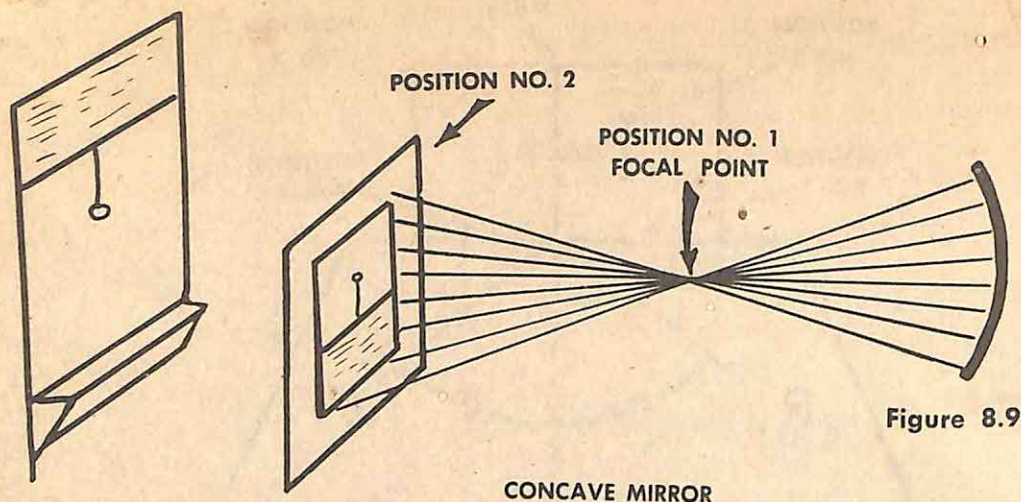


Figure 8.9

4. Projecting a Real Image with a Concave Mirror (Demonstration and Activity 5-6)

Materials: Concave shaving mirror and a sheet of tracing paper.

Procedure: Face the concave shaving mirror toward the windows of your classroom and hold a sheet of tracing paper about two inches from the reflecting side of the mirror, between it and the window. Slowly move the tracing paper away from the mirror, being sure to keep it in position in front of the mirror. Observe what happens to the light reflected onto the tracing paper by the mirror.

Discussion: As the paper is moved away from the mirror to position one (1), the light reflected from the mirror forms a small spot as illustrated in Figure 8.9. This is known as the *focal point*. The focal point is the distance from the mirror at which the reflected light rays from a very distant source meet and cross each other, causing the reflected image beyond the focal point to appear upside down and reversed. This reflected *real image* can be located by moving the paper farther away from the mirror. This position is illustrated in Figure 8.9 as position two (2).

Concave mirrors are used in reflecting type telescopes, ophthalmoscopes, and compound microscopes. The way in which they are used in these instruments would make ideal projects for the children to investigate.

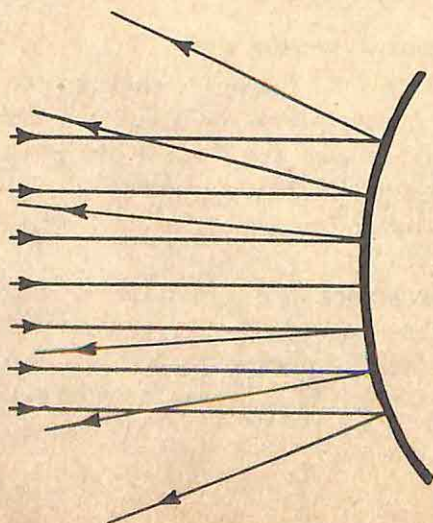


Figure 8.10

5. Convex Mirrors (Activity 5-6)

Materials: Convex automobile rear view mirror.

Procedure: A convex mirror is one in which the reflecting side curves toward you. Have a student hold a convex mirror close to the face of one of his classmates. Have the student looking in the mirror move away from the mirror slowly and report to the class what he observes happening to his reflection.

Discussion: The reflection of the student becomes smaller and smaller as he moves farther away from the mirror. The light rays are not reflected to a focal point as they are by the concave mirror; instead they are reflected in a wide area as illustrated in Figure 8.10.

6. Refraction of Light in Water (Demonstration 4-6)

Materials: Pie tin or shallow dish, water, and a coin.

Procedure: Place a coin in the center of a pie tin or shallow dish. Have the students in your class stand at a distance from the pie tin where they cannot see the coin above the rim of the pie tin. Pour some water into the pie tin and have the children report what they observe.

Discussion: The coin will appear to rise above the rim of the pie tin. The reflected light from the coin is bent as it passes through the water as illustrated in Figure 8.11. When light rays pass from a medium of one density to another of a different density, they are *refracted*.

7. Refraction of Light in Water (Demonstration 4-6)

Materials: Glass tumbler, water, and a pencil.

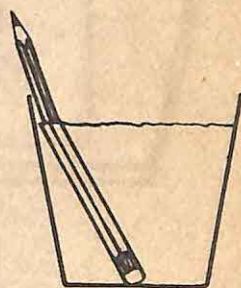
Procedure: Fill a glass tumbler with water and hold a pencil in it as illustrated in Figure 8.12. What appears to happen to the pencil?

Discussion: The pencil appears to bend because of the refraction of the light rays from the pencil reflected as they pass from the water into the air.

8. Proving Light Rays Bend (Demonstration and Activity 5-6)

Materials: Rectangular clear plastic box, flat headed nail, marking pen, ruler, sheet of paper 18 by 18 inches, and water.

Procedure: Draw an "X" in the center of the sheet of paper. Set the plastic box on top of the "X" so that the "X" is centered beneath it as illustrated in Figure 8.13(a). Fill the box $\frac{1}{2}$ to $\frac{3}{4}$ full with water and set a flat headed nail



REFRACTED LIGHT

Figure 8.12

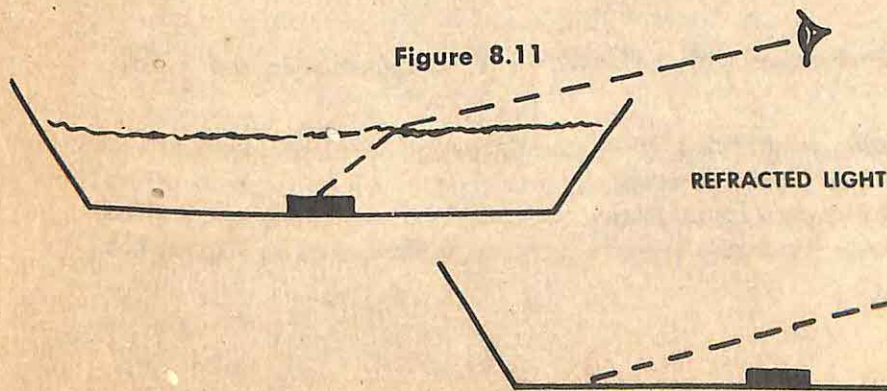


Figure 8.11

on its head in the water directly over the "X." Trace the outline of the box on the paper. Using a ruler, make several sightings along the paper to the image of the nail as seen through the water as illustrated in Figure 8.13(b). Draw several of these sightings, using a pencil or marking pen, at different places along the sides of the box. Remove the plastic box and connect the lines to the "X" on the paper. What do you observe about these lines?

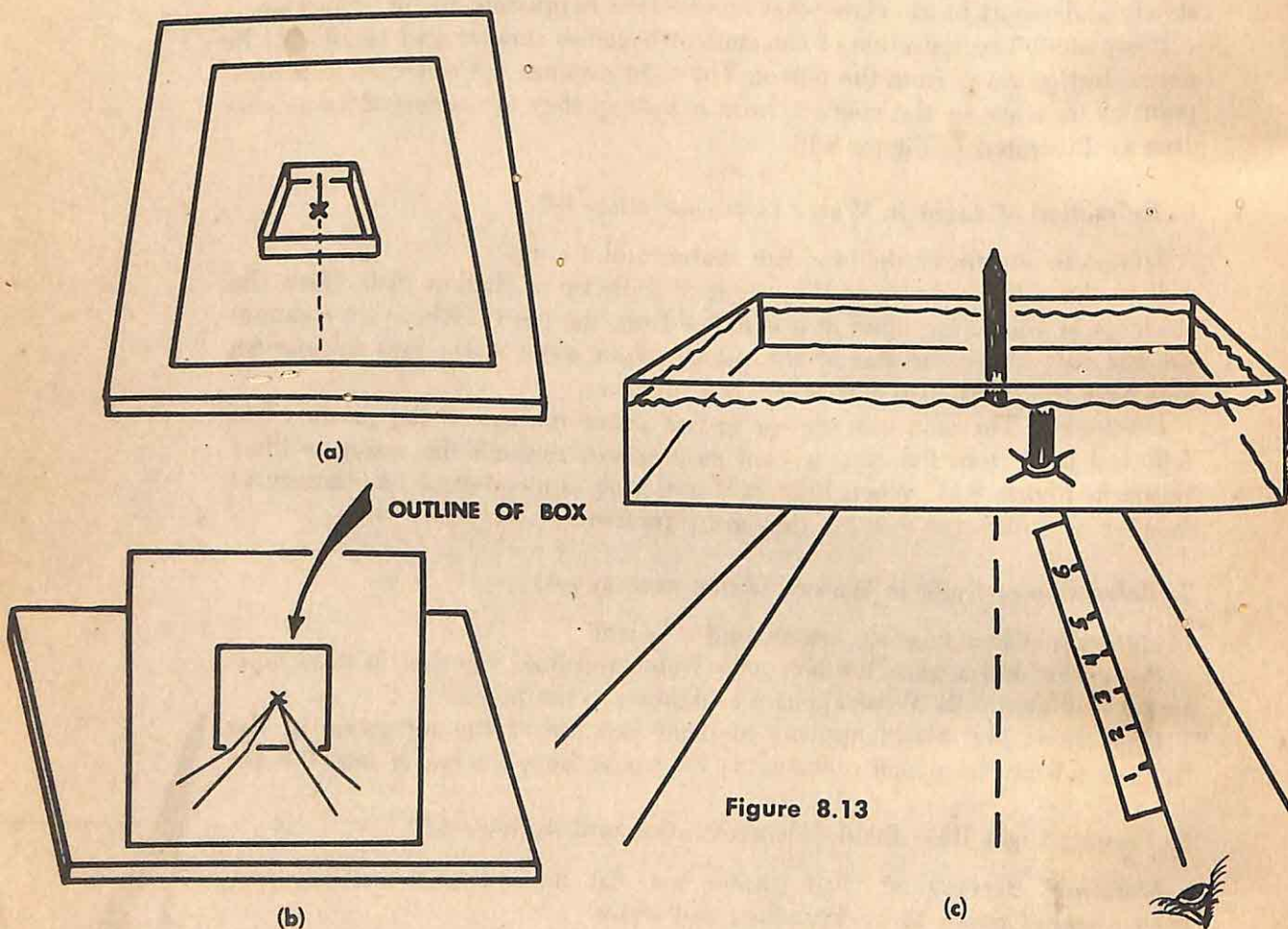


Figure 8.13

Discussion: The series of sight lines show how the reflected light rays were refracted as they passed from the water into the air as illustrated in Figure 8.13(c).

9. Projecting a Real Image with a Convex Lens (Demonstration and Activity 5-6)

Materials: Candle, magnifying glass, tracing paper, sheet of cardboard 12 by 12 inches, and two blocks of wood.

Procedure: Cut a square frame from a sheet of cardboard and tape a sheet of tracing paper over the frame to make a screen as illustrated in Figure 8.14.

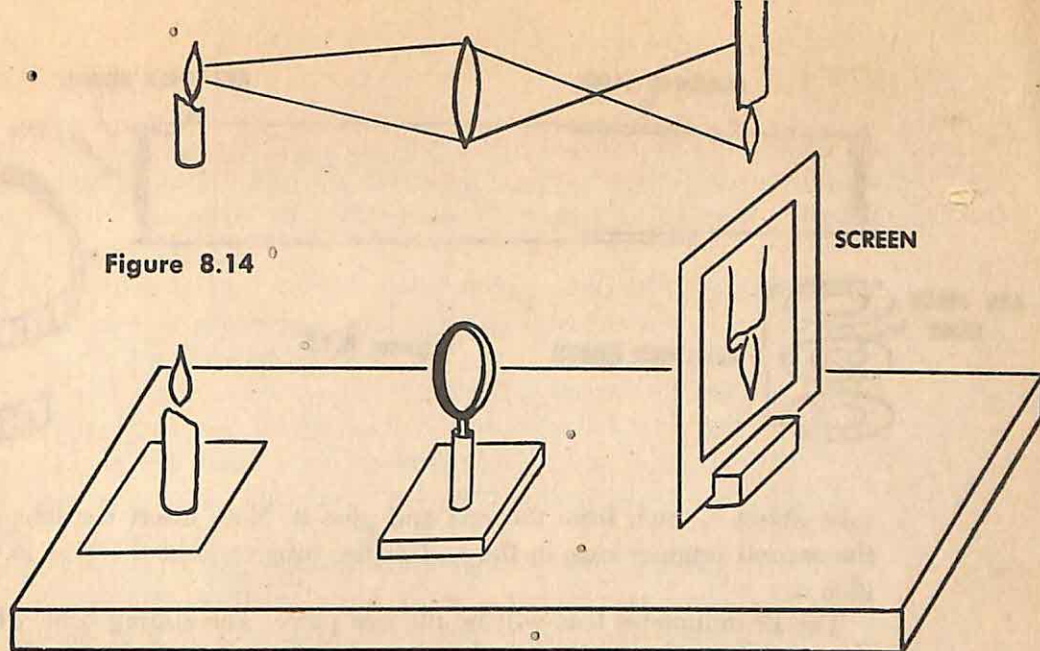


Figure 8.14

Set up the magnifying glass and the candle as shown. Move the magnifying glass between the screen and candle until the candle flame image is focused on the screen. What do you observe about the image on the screen? Move the magnifying glass closer to the candle flame, keeping the image on the screen in focus. What happens to the image?

Discussion: The flame image on the screen is upside down. It's reversed too but difficult to detect. As the magnifying glass is moved closer to the screen, the image gets smaller. This is due primarily to the fact that fewer light rays pass through the convex lens of the magnifying glass as the distance from the light source increases. As the magnifying glass gets closer to the candle flame, the image on the screen gets larger and fainter as the light rays are projected over a larger area of the screen.

A *convex lens refracts* light rays that pass through it to a focal point in much the same way that a *concave mirror reflects* light rays to a focal point. A real image that is upside down and reversed is produced beyond the focal point where the light rays cross each other.

10. Making a Refracting Telescope with Convex Lenses (Activity 5-6)

Materials: Optical kit of chipped lenses (from Edmunds Scientific Company, Barrington, New Jersey). Use plano convex lens (diameter 42 millimeters—about $1\frac{3}{4}$ inches), focal length of 201 millimeters—about 8 inches, and plano convex lens (diameter 19 millimeters—about $\frac{3}{4}$ inch), focal length 67 millimeters—about $2\frac{3}{4}$ inches; two cardboard cylinders (one with a diameter smaller than the other); two strips of cardboard $\frac{1}{4}$ inch wide and 6 inches long; a sheet of cardboard; and tape.

Procedure: The construction of the telescope is illustrated in Figure 8.15. The 42 millimeter lens will be the objective lens. Since the focal length of the 42 millimeter lens is about 8 inches, the cardboard tube will have to be at least 8 inches, preferably 9 inches long. The objective lens can be held in place by two cardboard retainer rings. Place one retainer ring inside the end of the

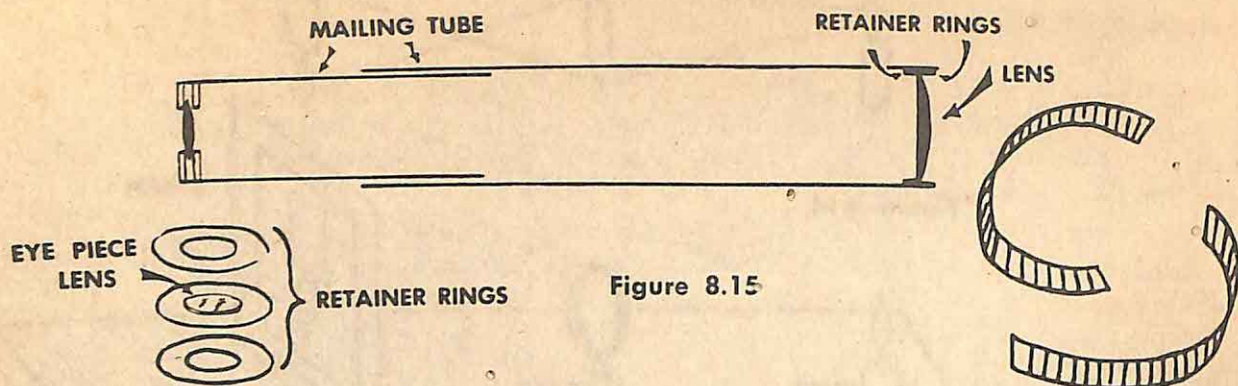


Figure 8.15

tube about $\frac{1}{4}$ inch from the end and glue it. Now insert the lens and place the second retainer ring in the end of the tube to hold the lens in place and glue it.

The 19 millimeter lens will be the eye piece. The sliding tube which holds the eye piece should be 6 inches long to allow enough length for focusing. The eye piece lens can be fixed in place in a sandwich fashion by using three cardboard rings as shown in Figure 8.15. The lens is fitted inside the hole in the center ring with the holes in the outer rings slightly smaller than the lens. Fasten the lens sandwich to the end of the smaller sliding tube.

Discussion: Aim your telescope at a distant object and focus the image by sliding the tube back and forth until the image is clear. This telescope will magnify objects 3 times. Can you figure out why? This activity may also provide a good opportunity to begin a study of the metric system of measurement.

11. Making a Pinhole Camera (Activity 5-6)

Materials: Oatmeal box, aluminum foil, pin, masking tape, black paper or black tempera paint, a paint brush, and some sheet film.

Procedure: The first step in making a pinhole camera is to blacken the inside of an oatmeal box with black tempera paint or line it with black construction paper. Blacken the inside of the box top too. Can you think of a reason why it is necessary to blacken the inside of the box? Next, cut a hole about the size of a nickel in the bottom of the box. Cover the hole with a sheet of aluminum foil, taping it to the outside of the bottom as illustrated in Figure 8.16(a). Punch a pinhole through the aluminum foil as shown.

The top of the box will make a fine film holder. Place some masking tape with the sticky side out on the inside of the top of the box as shown in Figure 8.16(b). This will hold the film that you will load under a portable dark room, which you will learn to make in the next activity of this section.

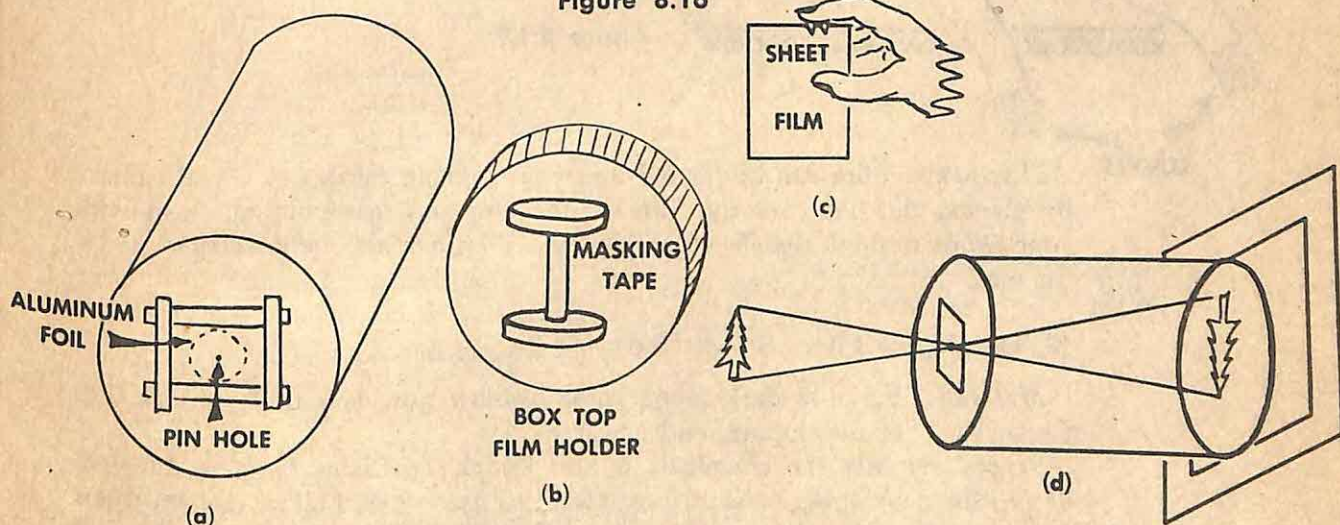
To take a picture with your pinhole camera you must have a shutter to control the amount of light you want to enter the camera to expose the film. A piece of black tape over the pinhole will make a satisfactory shutter to block out the light. To load your camera, place it under the portable dark room; cut a roll of film into sections large enough to fit on the film holder. The emulsion side, that side of a roll of film which is not covered with paper backing, should face the pinhole through which the light enters the camera. For inexperienced photographers it might be wise to start out using 4 by 5

inch sheet film. It is a little more expensive but will save time and confusion. In the dark room the emulsion side can be determined by holding the film in the right hand with your right index finger on the *code notches* of the film as illustrated in Figure 8.16(c).

After you have loaded the film, you are ready to expose it. Aim your camera at an object you desire to photograph and pull the tape from over the hole. How long do you expose the film? This answer you will have to find out for yourself by trial and error experimentation, keeping records of various exposure times. If the object is in bright sunlight, the exposure time will be less than if the object is in the shade. This is where the fun and excitement really begin. Remember, though, the film must be loaded, unloaded, and developed in a dark room.

- To find out how an image is projected on the film, try the following activity. Take your pinhole camera outdoors on a bright, sunny day and aim it at an object. Place a sheet of tracing paper over the open end of the camera, where the film holder would normally be, and observe the image. Refer to Figure 8.16(d) to find out why the image is upside down and reversed.

Figure 8.16



Discussion: Good results can be obtained with a pinhole camera and much can be learned about photography and the physics of light.

Figure 8.16(d) illustrates how the pinhole acts like a convex lens, projecting a real image on the film. For the light rays at the bottom and top of the object to travel in a straight line and still get through the hole, they must enter the hole at an angle. Can you see why the real image is upside down and reversed?

12. Making a Portable Dark Room (Activity 5-6)

Materials: Cardboard box 18 by 18 by 18 inches, two sleeves from a heavy dark sweat shirt, some black cloth, and masking tape.

Procedure: Construct a portable dark room as illustrated in Figure 8.17. Tape a strip of black cloth around the open bottom of the box. Tape the dark sleeves over the arm holes which are cut in the side of the box.

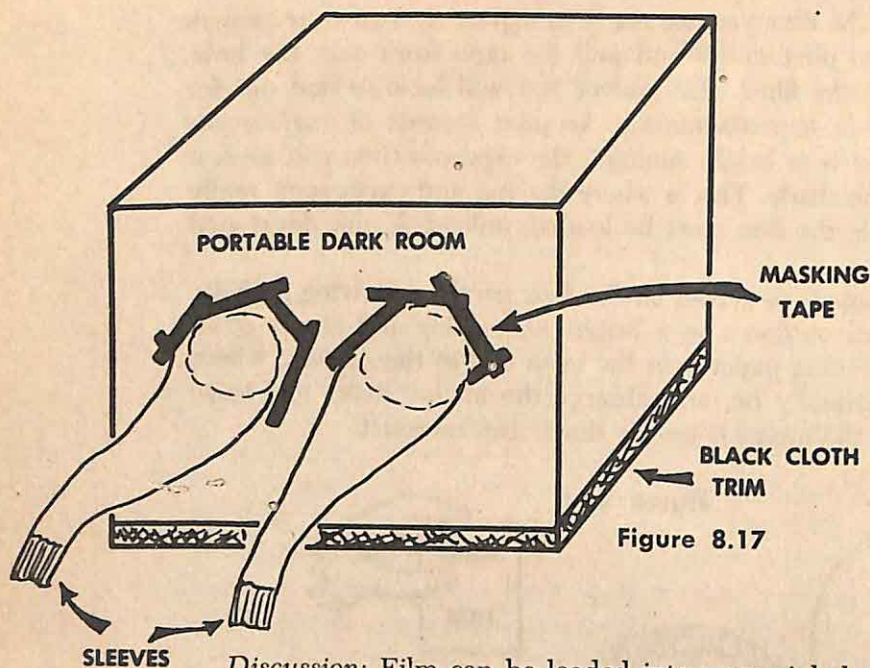


Figure 8.17

Discussion: Film can be loaded into your pinhole camera or a real camera by placing the box over the film and camera and manipulating them with your hands through the sleeves in the box. Film can also be developed under the box.

13. Developing Film (Activity 5-6)

Materials: Portable dark room, three shallow porcelain trays, Kodak Tri-Chem Pack for developing, and a watch.

Procedure: Mix the chemicals in the Kodak Tri-Chem Pack as directed. Set up the developing pans as illustrated in Figure 8.18. Follow the directions for developing the film found on the information sheet included in the film package.

Discussion: Your film will provide you with negatives which can be printed into pictures.

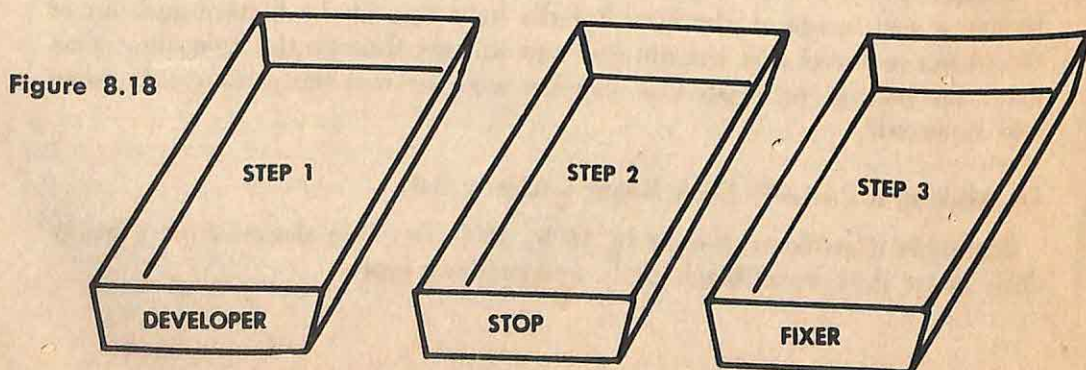


Figure 8.18

14. Making Contact Prints From Negatives (Activity 5-6)

Materials: Photographic paper in 8 by 10 inch sheets (Kodak Velite), desk lamp (100 watt bulb), three shallow pans, Kodak Tri-Chem Pack for developing, watch, and an 8 by 10 inch window glass.

Procedure: Place the Velite paper flat on a desk top and arrange the negatives on it, dull (emulsion) side down. Cover the paper and negatives with the 8 by 10 inch sheet of window glass as illustrated in Figure 8.19. Place the desk lamp over the window glass at a height of about 12 inches. Expose the Velite paper to the light for about 5 seconds. Remove the Velite paper from under the glass and start the developing process.

Set up the developing trays as illustrated in Figure 8.18. Submerge the exposed Velite paper into the *developing solution* and agitate for 1 to 2 minutes or until you get a print which is developed to your liking. Next, place it in the *stop bath* for 20 seconds and then into the *fixer* for about 10 minutes. Wash the print in water for 20 minutes.

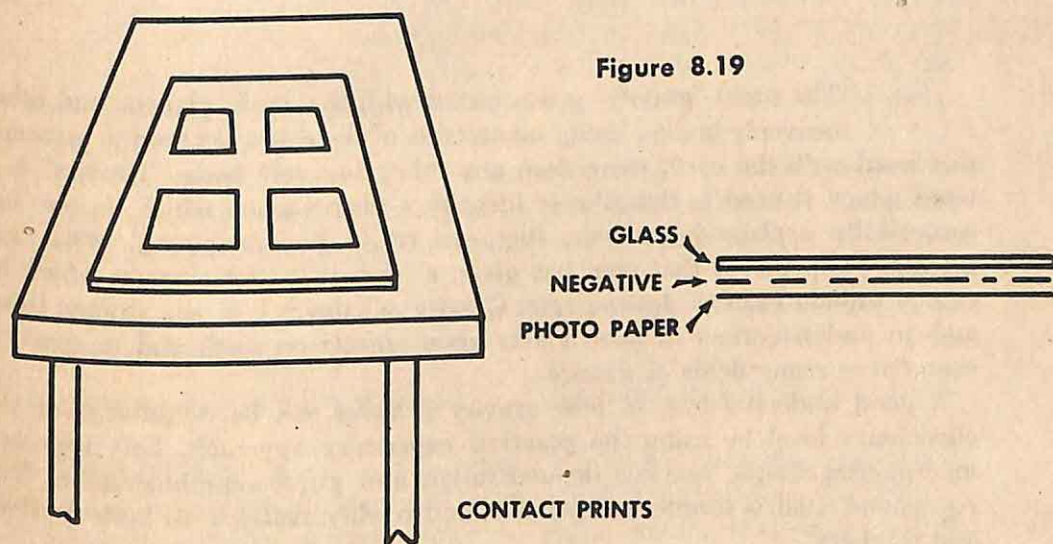


Figure 8.19

Discussion: Satisfactory contact prints can be made without entering a dark room by inexperienced photographers using Velite paper. Velite paper is not sensitive to normal classroom lighting. As a precaution, switch off all the lights in the classroom and draw the draperies or shades over the windows before exposing the paper. Above all, do not expose the paper to direct sunlight. With your room darkened, more than adequate light will be available to work under.

IX



Studying Gravity and How It Behaves

The word "gravity" is associated with the earth, planets, and other heavenly bodies. Being inhabitants of the earth, we tend to associate this word with the earth more than any other heavenly body. "Gravity" is a word which is used to describe or identify a phenomenon which no one has successfully explained in terms that can really be understood. What has actually happened is that man has given a label to a phenomenon which he cannot explain but can demonstrate. Gravity, whatever it is, is a strange thing and an understanding of how it acts upon objects on earth and in space is essential in many fields of science.

A good understanding of how gravity behaves can be established at the elementary level by using the practical experience approach. This approach incorporates simple teacher demonstration and pupil experimentation. The equipment used is simple, inexpensive, and readily available to both students and teachers.

A. GRAVITY, SIZE, AND WEIGHT

1. Gravity Gives Weight to All Objects (Demonstration and Activity 2-6)

Materials: Spring scale and several objects of various sizes and shapes.

Procedure: Weigh each object and read the weights indicated on the face of the scale.

Discussion: Gravity gives objects weight. All objects have weight because gravity pulls them toward the center of the earth.

2. Size and Shape and the Weight of an Object (Demonstration and Activity 2-6)

Materials: Spring scale, brick, balloon, block of wood, and a block of iron or some other heavy metal.

Procedure: Weigh each object and note the relationship of its weight to its size and shape.

Discussion: The balloon is larger than the brick, block of wood, or block of iron; yet it weighs the least.

3. Free Falling Objects Fall at the Same (Rate of) Speed (Demonstration and Activity 4-6)

Materials: Pencil, book, eraser, ruler, and coin.

Procedure: Hold two of the above objects at the same height and release them at the same instant. Observe which object strikes the ground first. Continue the experiment using two different objects each time until you have compared all the objects and how they fall.

Discussion: All the objects will strike the floor at the same time if released at the same instant from the same height. This is Galileo's Law of Free Falling Objects. There is, however, another part to this law, concerning the effect of the resistance of air to free falling objects, which will be investigated in the next demonstration. It should also be noted that we are stretching the point a little bit because the objects used are not dropped from a great enough height to allow the resistance of air to act upon them. For the law of free falling objects to work with all objects of all sizes and shapes, the demonstration would have to be performed in a complete vacuum.

4. The Effect of the Resistance of Air on Free Falling Objects (Demonstration and Activity 4-6)

Materials: Pencil, coin, eraser, sheet of paper, feather, and milkweed pod seed.

Procedure: Hold the pencil and the sheet of paper at shoulder height and release them at the same instant. Observe which object strikes the ground first. Repeat the experiment using the coin and the feather, the eraser and the milkweed pod seed. Observe which object strikes the floor first in each case.

Discussion: In all cases, the pencil, coin, and eraser will strike the floor first. The paper, feather, and milkweed pod seed are affected more by the resistance of air than the pencil, eraser, and the coin. To prove the point further, take the sheet of paper and crumple it into a ball. Now hold the paper ball and the eraser at the same height and release them at the same instant. Which one reaches the floor first?

5. Making a Spring Scale (Activity 3-6)

Materials: Bed spring coil, two boards 6 by 6 inches, sheet of cardboard 4 by 12 inches, and 4 or 5 one pound clay weights.

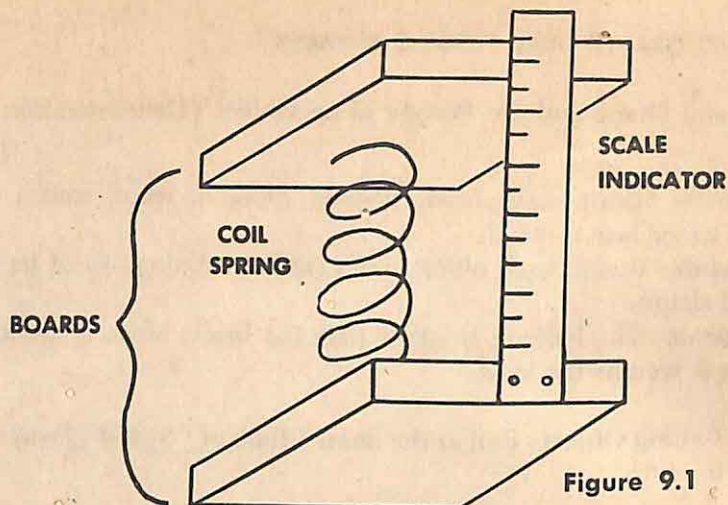


Figure 9.1

Procedure: Assemble the above equipment as shown in Figure 9.1. Fasten the coil spring to the boards, using small nails and bending them over the wire of the coil spring. Attach the sheet of cardboard to the side of the bottom board. Place a one pound weight on the upper board (platform) and mark the card with a pencil at the point to which the platform was lowered by the weight. Add the next one pound weight and mark the card again. This will be the two pound mark. Add the third, fourth, and fifth weights and mark the card as before.

Discussion: We now have a spring scale which can weigh objects up to five pounds. How can we increase the number of pounds that our scale can measure? The bathroom scale in your home operates much the same as ours does. What we are really measuring here is the effect of the force of gravity on the mass of the clay weights placed on the scale. Do you think gravity would have the same effect on the clay weights at an altitude of 100 miles above the earth?

B. STABILITY AND GRAVITY

1. Weight Distribution and the Stability of an Object (Demonstration and Activity 4-6)

Materials: Block of clay $2 \times 2 \times 1$ inches, pencil, and another block of clay $1 \times 1 \times \frac{1}{2}$ inches.

Procedure: Place the eraser end of a full length pencil into the center of the larger block of clay so that it stands straight up and is held firmly in place as illustrated in Figure 9.2. We now have an object which looks like a flag pole stuck in the ground. It has a heavy base and will not tip over easily. Now push the other end of the pencil through the center of the other block of clay and press the sides of the clay block so that it remains near the top of the pencil. Is it easier to tip over now? Shift the weight to a position one inch lower on the pencil. How easy is it to tip over now? Continue lowering the clay weight and testing the flag pole's stability.

Discussion: The flag pole will be top heavy when the weight is high. As the weight is lowered, it will become more difficult to tip the pole over.

Gravity pulls all objects toward the center of the earth, giving them weight. As the flag pole was tipped over with the weight high, gravity pulled the weight toward the ground, causing the pole to fall to its side. Because the weight remains more nearly over the base when it is lower on the pole, the pole must be tipped farther to get the weight over to a point where gravity will pull it down.

2. Weight Distribution and the Stability of an Object (Demonstration and Activity 4-6)

Materials: Same as for Demonstration 1 above.

Procedure: For this demonstration use the small block of clay for the base of the flag pole and the larger block of clay for the movable weight. Test the pole for stability as the larger block of clay is lowered toward the small base.

Discussion: The flag pole is very unstable and will tip over without any force being applied, when the large weight is at the top. As the large block is lowered, the pole becomes more and more stable. The lower the weight, the lower the center of gravity and the more stable is the object.

3. Experimenting with the Size of the Base of an Object (Demonstration and Activity 4-6)

Materials: Same as Demonstrations 1 and 2 above.

Procedure: Set the large block of clay on a sheet of paper and place the end of the full length pencil into the center of it so that it stands up straight and is held firmly in place. Now flatten the large block of clay so that it forms a wide base as illustrated in Figure 9.3(a). Be sure to leave enough clay around the bottom of the pencil so that it will remain firmly erect. Using the smaller block of clay, move it up and down the pencil to check the stability of this pole with the wider base. What happens?

Next, change the shape of the larger block of clay once again by squeezing the clay together into a tall, thin base as illustrated in Figure 9.3(b). Again check the stability of the pole by moving the smaller clay block up and down on the pencil. What happens?

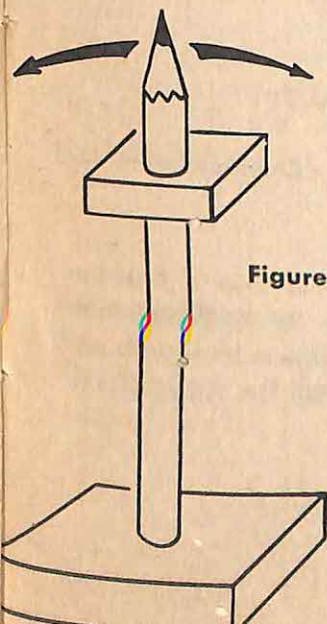
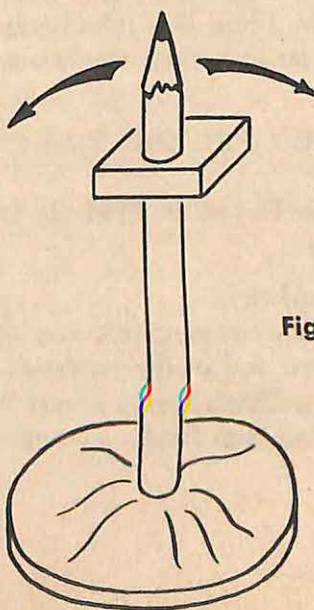
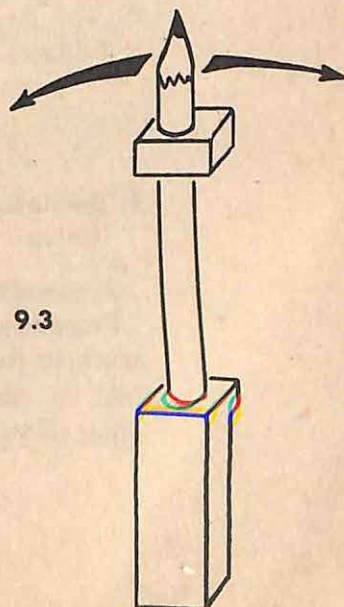


Figure 9.2



WIDE BASE



NARROW TALL BASE

Discussion: As the base of the object is broadened, the object becomes more stable. As the base of the object is made smaller, it becomes less stable. Objects which are short and squat with the majority of their weight near the ground are more stable than objects which are tall and thin.

4. Experimenting with the Weight of an Object and Its Stability (Demonstration and Activity 4-6)

Materials: Quart jar with screw on lid, water, rubber band, ruler, tape, and string.

Procedure: Tie a string to the neck of a jar and attach a rubber band to the string. Tape one side of the base of the jar to the desk top. Test the stability of the empty jar. We can test the stability of the jar by pulling on the rubber band and measuring with the ruler how much it stretches as illustrated in Figure 9.4. The tape will act like a hinge and prevent the jar from sliding on the desk as you pull on the rubber band. Pull on the rubber band and allow it to stretch to the point where the jar is on the verge of tipping over. Hold it in this position and have someone measure the length of the rubber band. Record your results. Repeat the experiment several times as you add weight to the jar by pouring water into it. Each time you stretch the rubber band and tilt the jar, record the length of the rubber band. What are the results of this experiment? When is the jar most stable?

Discussion: As water is added to the jar, the force needed to tip the jar over—to overcome the weight given it by gravity—becomes greater. This is well indicated by the distance the rubber band must be stretched to provide enough force to tip the jar as water is added to it. Heavier objects are *usually* more stable. Heavy objects with a wide base are more stable than light objects with a narrow base. Can you think of times when this would not be true?

Another approach to this activity would be to determine the length the rubber band, used as a scale, will stretch when 1 pound, 2 pound, 3 pound, 4 pound, and 5 pound weights are suspended one at a time from it. Then when the jar is tipped by pulling on the rubber band, the distance the rubber band is stretched can be measured and converted into pounds of force required to tip the jar over. From this information a good quantitative analysis of the stability of the jar in various conditions can be made.

C. FINDING THE CENTER OF GRAVITY

1. Balancing an Object to Find Its Center of Gravity (Demonstration and Activity 4-6)

Materials: Yardstick.

Procedure: Place the yardstick over the outstretched forefingers of your two hands so that one end of the yardstick projects out past one forefinger more than the other, as illustrated in Figure 9.5, keeping both fingers level with each other. If we bring both forefingers together, which way will the yardstick fall?

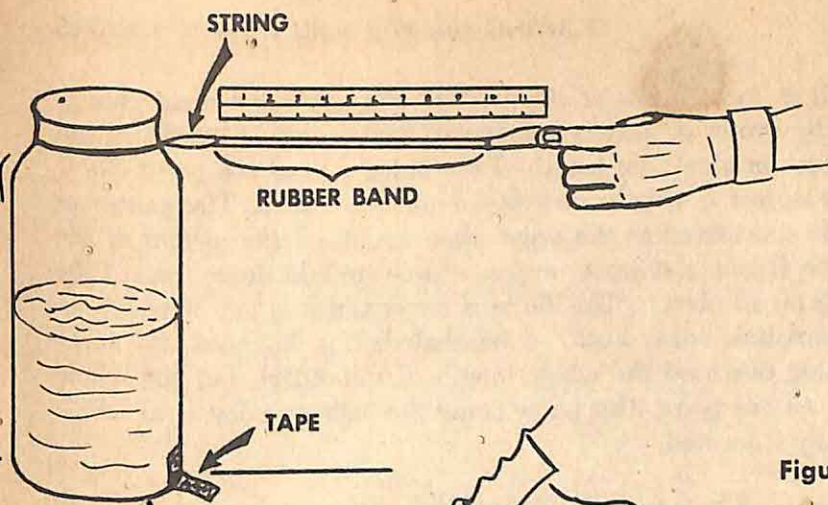


Figure 9.4

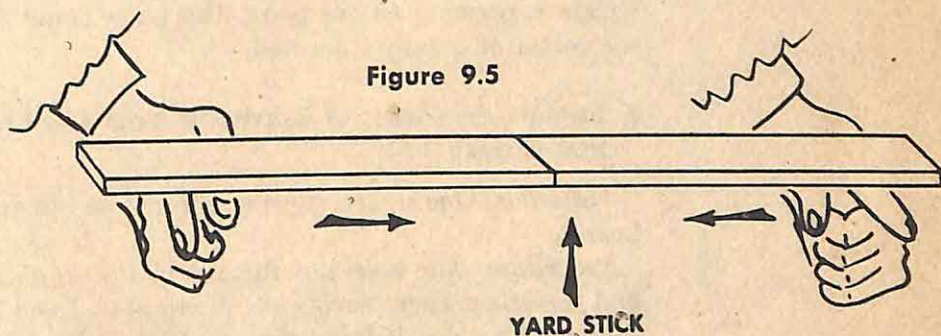


Figure 9.5

Discussion: The yardstick does not fall at all. Both forefingers end up in the center of the yardstick at its center of gravity. Why? The end of the yardstick that projects over the farthest presses down with a greater force than the shorter end. As the fingers are brought together, the finger with the least weight on it will slide more easily under the yardstick until there is an equal amount of weight on both fingers. At this point, both fingers will move toward the center of the yardstick until the yardstick is balanced at its center, which is the center of gravity.

2. Balancing an Object to Find Its Center of Gravity (Demonstration and Activity 4-6)

Materials: Yardstick, ruler, baseball bat, book, and block of wood.

Procedure: Tell the children that you are going to find the center of gravity of the above objects. To do this, place the yardstick, ruler, and book on a balance point (block of wood) and adjust their weight so as to balance them. As each object is balanced, mark the point of balance on each object and refer to it as the "center of gravity" of the object. After this activity has been completed, ask the children to give a definition of the center of gravity. Now balance the baseball bat. Where does it balance?

Discussion: The first and most obvious definition of the center of gravity will probably be, "the center of gravity of the yardstick and ruler is at their centers where they balance." This is true if the object is of uniform shape and thickness. We can consider the yardstick and ruler as such objects. The baseball bat, however, is not considered to be of uniform shape and thickness. It is "fatter" on one end than on the other. Its balance point is not at the center

along its length. It is located nearer the "fatter" end. Now we must change our definition of the center of gravity somewhat. The center of gravity is not necessarily at the center along the length of the object but *at the point where the weight of the object is evenly distributed on both sides*. The center of gravity can also be considered as the *point upon which all the weight of the object presses when balanced*. Gravity exerts a force straight down toward the center of the earth on all objects. This force is never tilted in any other direction. When the yardstick, ruler, book, or baseball bat is balanced, the force of gravity is pushing down on the whole length of the object, but the whole weight is pressing on one point—this point being the balance point over which the center of gravity is located.

3. Finding the Center of Gravity by Trial and Error Method (Demonstration and Activity 4-6)

Materials: One square sheet of cardboard and one rectangular sheet of cardboard.

Procedure: The object of this method of finding the center of gravity is to find the point where each sheet of cardboard will balance. Where is this point located? Can you balance the sheet of cardboard on your finger tip?

Discussion: By trial and error the center of gravity of each sheet of cardboard can eventually be located. This is the point at which the cardboard sheet should balance on your finger tip. The balance point is once again found to be the center of gravity of an object. Is there another way to find the same point?

To find out what effect a small bit of extra weight might have on the center of gravity of either the square or rectangle, attach a paper clip to one corner and have the children balance it on their finger tip. Does the center of gravity change?

4. Finding the Center of Gravity by Drawing Diagonal Lines (Demonstration and Activity 4-6)

Materials: One square sheet of cardboard, one rectangular sheet of cardboard, ruler, and a pencil.

Procedure: The marks placed on the two sheets of cardboard in the previous activity to indicate their centers of gravity will be located at or very close to the center of each sheet of cardboard. How can we find the center of the cardboard sheets using another method?

Discussion: The conclusion arrived at will be as follows: if we draw two lines connecting the opposite corners of a square or rectangle as illustrated in Figure 9.6, the point where these lines intersect will be the center of each object. The center of gravity will also be at this point, and the lines drawn will cross over or very close to the mark indicating the "center of gravity." The center of gravity of such regularly shaped objects will usually be at or very close to their centers.

Gravity exerts a force on an object which is straight toward the center of the earth and through the object's center of gravity. Remember, we said that

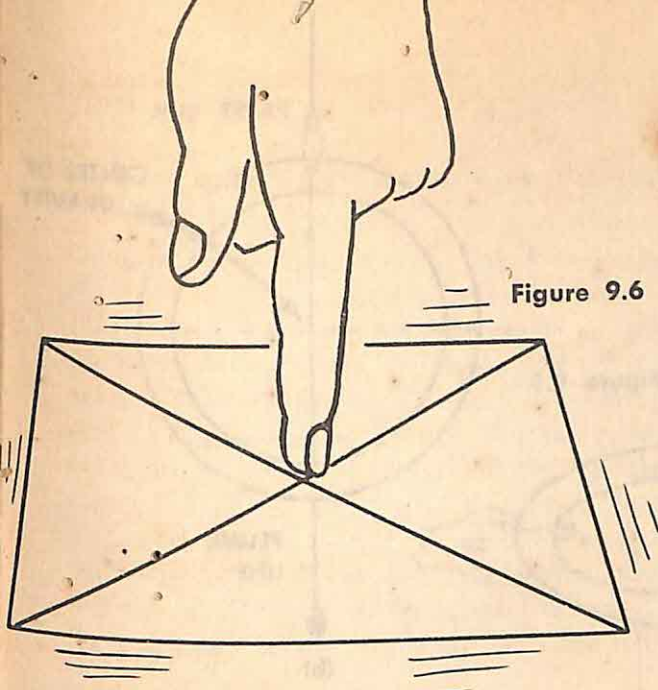


Figure 9.6

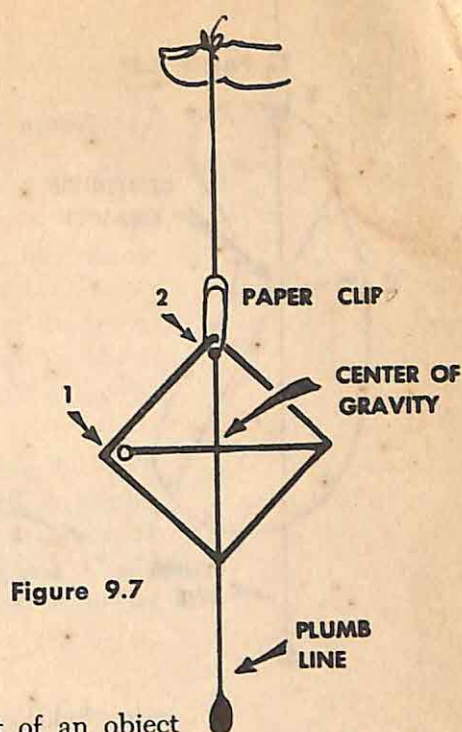


Figure 9.7

"the center of gravity is the point upon which all the weight of an object presses when balanced." The fact that gravity exerts a force which is straight down can be demonstrated.

5. Finding the Center of Odd-Shaped Objects Using the Trial and Error Method (Demonstration and Activity 4-6)

Materials: Several sheets of cardboard cut out in odd shapes.

Procedure: By trial and error find the center of gravity of each of the objects by balancing them on the tip of your finger. Mark the point of balance on each sheet of cardboard.

Discussion: The balance point is the center of gravity.

6. Gravity Exerts a Force Which Is Straight Down Toward the Center of the Earth (Demonstration and Activity 4-6)

Materials: Small clay weight suspended from a string.

Procedure: Suspend the weight by holding onto the end of the string until the weight and string are as motionless as possible. Does the string form a straight line from your hand to the weight?

Discussion: The string forms a straight line which follows the straight line force of gravity toward the earth. The straight line force of gravity should go through the center of gravity of the object suspended from the string too. Let's see if it does. Let us experiment with our square sheet of cardboard.

7. Finding the Center of Gravity by Using a Plumb Line (Demonstration and Activity 4-6)

Materials: One square cardboard sheet with its diagonals drawn and its center located, one paper clip, string, and small clay weight.

Procedure: Assemble the materials as illustrated in Figure 9.7 above. The

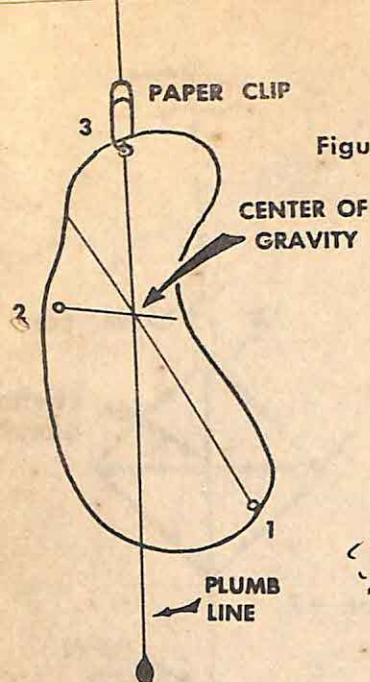


Figure 9.8

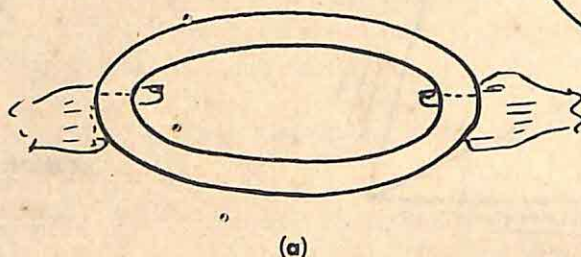


Figure 9.9

string holding the weight is separated from the string holding the cardboard square by the paper clip. Suspend the square from the two positions shown in the diagram. Does the string line up with the diagonals drawn on the square? Does the string cross at the center (the center of gravity) of the square?

Discussion: The string will line up with the diagonals on the square and cross at the center (the center of gravity) of the square.

8. Finding the Center of Gravity of Odd-Shaped Objects by Using a Plumb Line (Demonstration and Activity 4-6)

Materials: Several sheets of cardboard cut out in odd shapes, paper clip, clay weight, and some string.

Procedure: Suspend each object from several points along its edge as illustrated in Figure 9.8. Draw in the lines projected by the plumb line. Do these lines cross at the same point? Will the object balance at the place where the lines cross?

Discussion: The lines will all intersect at a single point, and the object will balance at this point. This point is the center of gravity of the object.

9. Finding the Center of Gravity of a Disk by Using a Plumb Line (Demonstration and Activity 4-6)

Materials: Cardboard disk 8 inches in diameter, paper clip, clay weight, and some string.

Procedure: Using the trial and error method, find the center of gravity of the disk by balancing it on your finger. Suspend the disk from several points along its circumference, using the plumb line. Draw the lines projected by the plumb line.

Discussion: The lines will cross at a single point on or very close to the mark where the disk balanced on your finger tip. This point is the center of gravity of the disk.

10. Finding the Center of Gravity of a Hoop by Using a Plumb Line (Demonstration and Activity 4-6)

Materials: Cardboard hoop with 8 inch outside diameter and 7 inch inside diameter, paper clip, clay weight, and some string.

Procedure: Try to locate the center of gravity of the hoop by using the trial and error method of balancing it on your fingers. What results do you obtain? Find the center of gravity using the plumb line as you did with the disk in Demonstration 9 above. Are the results the same?

Discussion: Using the trial and error method, you will find that the hoop can only be balanced if held up at two points only as illustrated in Figure 9.9(a). When you use the plumb line, you find that the center of gravity is at the center of the space inside the hoop as illustrated in Figure 9.9(b). Could this be so? Consider the location of the center of gravity of a hollow rubber ball, that of a square cardboard box, and that of the earth.

D. STABILITY AND THE CENTER OF GRAVITY

1. Stability and the Location of the Center of Gravity (Demonstration and Activity 5-6)

Materials: Two cardboard boxes with the same base dimensions, one twice as tall as the other; a string with a small clay weight on one end (plumb line); a nail; two metal rods made from a wire coat hanger; and a 4 foot board 6 inches wide and one inch thick.

Procedure: Display the two boxes and ask the children where they think the center of gravity of each box is. The center of gravity will be somewhere inside the empty space in the box. This point can be found by drawing diagonals on all four sides of the box and locating the center of each side. Punch holes at each of these four points and insert the two rods between opposite sides of the box as illustrated in Figure 9.10(a). The point where the two rods intersect is the center of gravity. Tie a string to the rods at this point and try it.

After finding the center of gravity of the two boxes, check their stability in the following manner: place both boxes on an inclined plane, as shown in Figure 9.10(b), with plumb lines attached to the center of one side of each box at the hole already punched. Hold the boxes on the inclined plane and note the position of the plumb line of each box. Lift the board at one end to create an inclined plane until the plumb line of the tall box is at a position outside its base. Then let go of each box. What happens?

Discussion: The force of gravity pulls all objects straight down toward the center of the earth. The plumb lines represent the vertical pull of the force of gravity through the center of gravity of each box. The plumb line of the shorter box did not extend outside its base when the plumb line of the taller box did. Consequently, the shorter box did not tip over, while the taller one did. The taller box has a high center of gravity and tips over easily once its center of gravity extends outside its base.

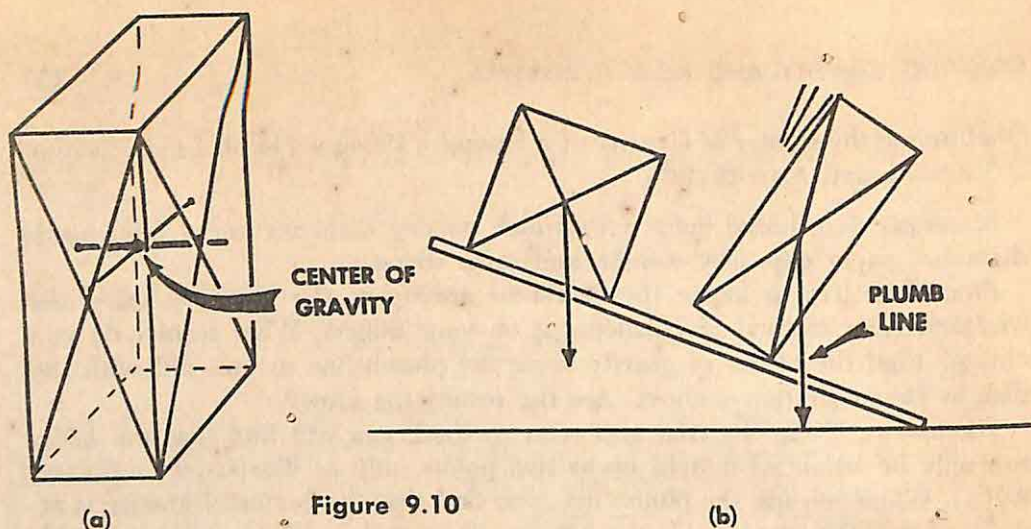


Figure 9.10

2. The Stability of a Ship and Its Center of Gravity (Demonstration and Activity 4-6)

Materials: Twelve inch long 2-by-4 cut into the shape of a ship, 12 inch long $\frac{1}{4}$ inch round dowel, aquarium with water, and a clay weight.

Procedure: Bore a $\frac{1}{4}$ inch hole in the middle of the board and insert the $\frac{1}{4}$ inch round dowel into the hole as illustrated in Figure 9.11. Place the model ship in the aquarium. Push the top of the mast (dowel) through the center of a clay weight. The clay weight should be heavy enough to cause the model ship to capsize (tip over) when it is at the top of the mast. Place the clay weight at various heights on the mast and check the ship for stability. At what position is the weight when the ship is most stable? At what position is the weight when the ship is least stable?

Take the weight off the mast and place it first on one side of the ship and then on the other side. Place it in the middle of the ship. What happens?

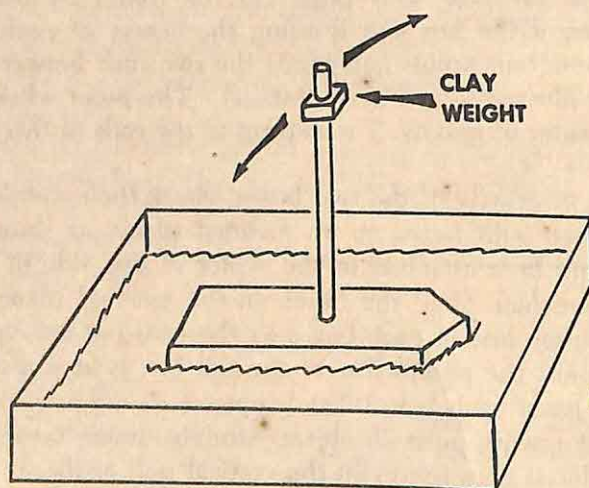


Figure 9.11

Discussion: With the weight high on the mast, the ship is very unstable and will capsize easily. As the weight is lowered, it becomes more difficult for the ship to capsize. Ship builders try to keep as much of the weight of a ship as low as possible in order to lower the center of gravity. If the center of

gravity is high, it is easy for the ship to capsize in a storm. Ship builders also try to keep the weight of the ship centered so that it will not lean (list) to one side while floating in the water.

3. The Stability and Center of Gravity of an Automobile (Demonstration and Activity 4-6)

Materials: Two shoe boxes of identical size, four axles (wooden dowels), eight wheels, and a plumb line.

Procedure: Fix two axles with wheels on the long sides of one shoe box as illustrated in Figure 9.12(a). Fix two axles with wheels as high up on the second shoe box as possible and still allow the wheels to extend below the bottom of the box. Draw diagonals to find the center of one end of each box. Insert a pin at each center and suspend a plumb line from it as illustrated in Figure 9.12(b). Tilt each box to one side, keeping it on its wheels, and note which box can be tilted the furthest without tipping over.

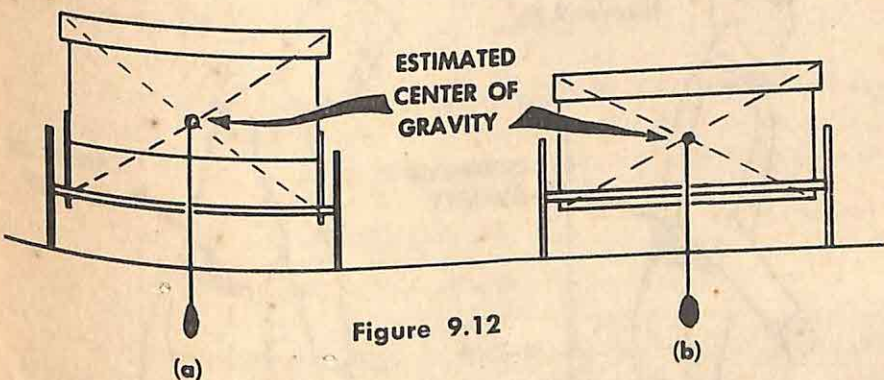
Discussion: The two boxes represent two cars of different design. One is built with its weight very low and the other with its weight high, the lower car being more stable. You will be able to tip the low car further on its side than the high car. The plumb line gives evidence of this. Once the plumb line extends outside the wheel base, the car will tip over.

E. THE CENTER OF GRAVITY AND HUMAN BEINGS

1. The Force of Gravity Acting on the Center of Gravity of a Human Being (Demonstration and Activity 4-6)

Materials: Plumb line.

Procedure: Tie a plumb line to your belt at the front of your body. Place your feet together and lean to one side with your body stiff as illustrated in Figure 9.13. Lean until you start to lose your balance and tip over. Remember:



remain stiff. Have the children observe the plumb line. Where was it when you lost your balance?

Discussion: As you lean to the left or right, the plumb line moves past the outside edge of your foot. At this point you lose your balance because the force of gravity is acting on the center of gravity of your body, which is now in a position beyond the foundation holding you up—your feet.

2. Shifting Body Weight to Keep Our Balance (Demonstration and Activity 4-6)

Materials: Plumb line.

Procedure: Same as for Demonstration 1 with the following exceptions. As you lean to the left or right, this time raise the opposite leg in an attempt to keep your balance as illustrated in Figure 9.14. What happens to the position of the center of gravity of your body? What happened to the plumb line?

Discussion: The muscles of your body will shift your weight in an attempt to retain your balance. This time the center of gravity will move to a position directly over the foot that is on the floor acting as the balance point (fulcrum), and the plumb line will follow your leg down toward that foot.

3. The Force of Gravity Acting on the Center of Gravity of a Human Being (Demonstration and Activity 4-6)

Materials: Plumb line.

Procedure: Tie a plumb line to your belt at the center of the side of your body. Place your heels against a wall and rest your back and head against the wall. This will place you in a straight upright position. Start to lean forward slowly with your body in a rigid pose until you just begin to lose your balance. Have the children observe the plumb line. Where was it when you lost your balance?

Discussion: As you lean forward, the plumb line indicates the position of the center of gravity beyond your toes as illustrated in Figure 9.15. At this point

Figure 9.14

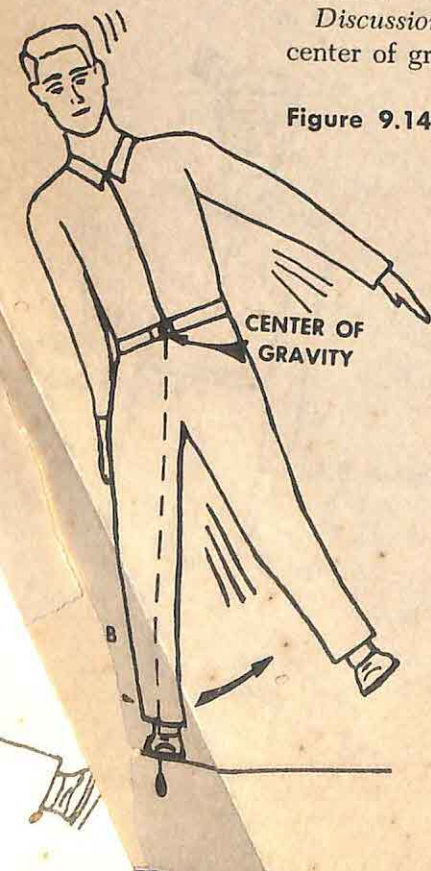


Figure 9.15

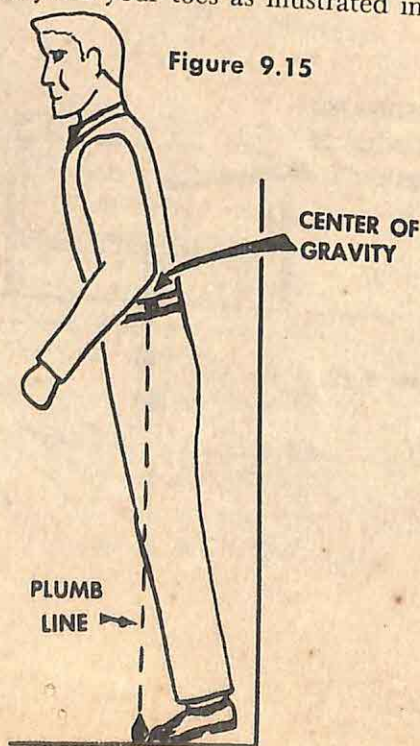
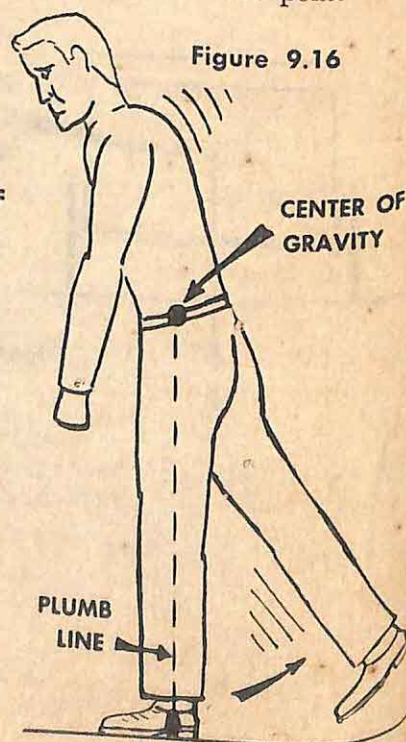


Figure 9.16



you lose your balance because the force of gravity is acting on the center of gravity of your body, which is now in a position beyond the foundation holding you up—your feet.

4. The Force of Gravity Acting on the Center of Gravity of a Human Being (Demonstration and Activity 4-6)

Materials: Plumb line. (See Figure 9.16.)

Procedure: Tie a plumb line to your belt at the center of the side of your body. Stand away from the wall this time, lean forward on one leg, and raise the other leg behind you. What happens to the plumb line?

Discussion: The muscles of your body will shift your weight in an attempt to retain your balance. This time the center of gravity will move to a position directly over the foot that is on the floor acting as a balance point (fulcrum), as indicated by the plumb line which will follow your leg down toward that foot.

5. Our Ears and Our Balance (Demonstration 4-6)

Materials: Carpenter's level.

Procedure: The human ear has three semi-circular canals which help control our balance. These canals are filled with a fluid which moves when there is a movement of the head. As the fluid moves, it excites tiny hair-like nerve endings in each canal, which transmit messages to the brain indicating the status of the balance of the body. Each of the three canals sends different indications of movement to the brain for interpretation. One tells the brain about movements backward and forward. Another tells the brain about movement from side to side. The third tells the brain when there is a spinning movement.

Each of the semi-circular canals acts something like a carpenter's level. When the carpenter's level is tilted from the horizontal or vertical plane, the water in the glass tube moves to the lower end. This movement is indicated by the movement of the air bubble to the upper end of the glass tube. What happens to the air bubble when you tilt the carpenter's level to the right? To the left?

Discussion: When the carpenter's level is tilted to the right, the water, flowing downward, moves in the opposite direction—to the left. A similar action occurs to the fluid in the semi-circular canals in the ear.

6. Our Eyes and Our Balance (Activity 2-6)

Materials: Wooden 2-by-4 about 10 feet long.

Procedure: Set the wooden 2-by-4 on its edge with a student at each end to steady it. Have the other students walk the beam one at a time, using their bodies and arms in any manner necessary to keep their balance. After the students have become proficient in "walking the plank," have them try it with their eyes shut. How is balance affected when their eyes are shut?

Discussion: Our eyes play an important role in aiding us to keep our balance. They help us to predict what is to come and warn us of danger.

X



Earth and Sky

Acquiring an understanding of the earth, the solar system, and the other heavenly bodies is not an easy task for children at the elementary level. It is difficult, for example, for the children to accept the fact that the sun is bigger than the earth when it appears so tiny in the sky. It is even more difficult for them to believe that the stars they see at night are bigger than the moon and earth and that many are larger than the sun. Confusing them even more, we tell the children that the earth is a planet which is floating in space and is not held up by a metal bracket and pole as their classroom globe obviously shows them.

Whether or not the children ever really understand the relationship of distance and size and the fact that heavenly bodies are not held up in space by metal brackets depends on the individual and the techniques which the teacher uses in presenting these concepts to them.

With a good understanding of the force of gravity, the study of Earth and Sky will be made easier, for it is the forces of gravity which holds the solar system together and influences the ocean tides on earth.

A. SIZE AND DISTANCE OF HEAVENLY BODIES

1. Size of Sun, Earth, and Moon (Demonstration and Activity 2-6)

Materials: Two foot diameter globe covered with aluminum foil, $\frac{1}{4}$ inch diameter clay ball, $\frac{1}{16}$ inch diameter clay ball, and two straight pins.

Procedure: Mount the $\frac{1}{4}$ inch and $\frac{1}{16}$ inch clay balls on the ends of two separate pins. The $\frac{1}{4}$ inch clay ball represents the earth, the $\frac{1}{16}$ inch clay ball represents the moon, and the aluminum foil covered globe represents the sun. All of these models are at a true scale of 2 feet equals 860,000 miles (the diameter of the sun). Place the three models side by side.

Discussion: Comparing the size of the models in close proximity will help establish the fact that the sun is much larger than the earth and moon. It will also help to establish the size difference between the earth and the moon.

2. How Distance Affects the Size of the Sun as We See It (Demonstration and Activity 2-6)

Materials: Two foot diameter globe covered with aluminum foil, $\frac{1}{4}$ inch diameter clay ball mounted on a straight pin.

Procedure: The globe will represent the sun and the clay ball the earth. These are at a true scale of 2 feet equals 860,000 miles (the diameter of the sun). Compare the size of the two bodies to establish the fact that the sun is much larger than the earth.

Why does the sun look so small in the sky? Now take the globe 216 feet from the clay model of the earth and observe what appears to happen to its size.

Discussion: The sun will appear to get smaller as it gets farther away. This accounts for the reason that the sun looks so small in the sky. At a scale of 2 feet equals 860,000 miles, the earth would be 216 feet away from the sun. This figure is easy to obtain by dividing 93,000,000 miles (the distance of the sun from the earth) by 860,000 miles (the diameter of the sun) and multiplying the results by 2.

3. The Distance of the Moon From the Earth (Demonstration and Activity 2-6)

Materials: Two foot diameter globe covered with aluminum foil, $\frac{1}{4}$ inch diameter clay ball mounted on a straight pin, $\frac{1}{16}$ inch diameter clay ball mounted on a straight pin.

Procedure: The globe will represent the sun, the $\frac{1}{4}$ inch diameter clay ball the earth, and the $\frac{1}{16}$ inch diameter clay ball the moon. These are at a true scale of 2 feet equals 860,000 miles (the diameter of the sun).

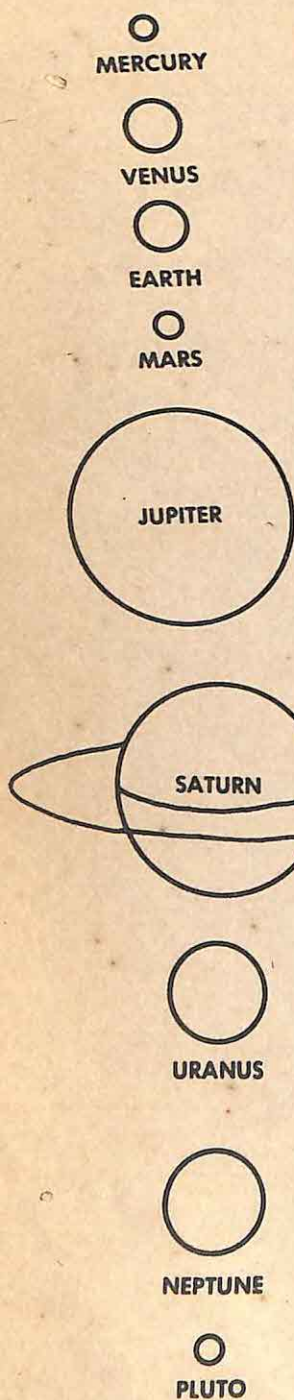
Discussion: Compare the size of the three bodies to establish the fact that the moon is smaller than both the sun and earth. The distance of the moon from the earth, at a scale of 2 feet equals 860,000 miles, would be about 7 inches. The moon is much closer to the earth than is the sun. This figure is arrived at by dividing 860,000 miles (the diameter of the sun) by 240,000 miles (the distance of the moon from the earth) and multiplying your results by 2. This procedure may seem to be redundant, but it is important to reinforce the concept of size and distance.

4. Scale View of the Size of the Planets in Our Solar System (Demonstration and Activity 4-6)

Materials: Modeling clay.

Procedure: Construct clay models of the planets of our solar system at a scale of 2 feet equals 860,000 miles as illustrated in Figure 10.1. It should be noted that Saturn is almost as large as Jupiter, but with its rings it is nearly twice the size of Jupiter. Each of these rings, however, is only about ten

Figure 10.1



miles thick. Compare the sizes of the model planets with each other and with the model sun.

Discussion: We now have a true scale picture of the size relationship of the planets in our solar system. To compute these sizes, divide 860,000 miles (the diameter of the sun) by the diameter of the planets, as listed below, and multiply the results by 2.

PLANET	DIAMETER IN MILES	SCALE SIZE 2 FT. = 860,000
Mercury	3,100	$\frac{1}{16}$
Venus	7,700	$\frac{1}{4}$
Earth	7,900	$\frac{1}{4}$
Mars	4,200	$\frac{1}{16}$
Jupiter	88,700	$2\frac{1}{2}$
Saturn	74,200	$2\frac{1}{4}$
Uranus	32,400	1
Neptune	31,000	1
Pluto	8,000	$\frac{1}{4}$

5. Scale View of the Distance of the Planets From the Sun (Demonstration and Activity 4-6)

Materials: Clay scale models of the planets, 2 foot diameter globe covered with aluminum foil to represent the sun, and a tape measure.

Procedure: Have the children measure out the distances provided in the chart below and carry the model planets to their designated distances from each other and from the sun. This can be done in the hall, gym, or out of doors.

PLANET	DISTANCE FROM SUN IN MILLIONS OF MILES	SCALE DISTANCE IN FEET 2 FT. = 860,000
Mercury	36	100
Venus	67	186
Earth	93	216
Mars	141	392
Jupiter	483	1,344
Saturn	886	2,540
Uranus	1,783	4,960
Neptune	2,794	7,780
Pluto	3,670	10,240

Discussion: The children will now have a good idea of the vastness of space in our solar system. They will see that if the planets are drawn to scale they could not possibly fit on a single or even a double page in a science textbook. The pictures found in textbooks and charts of the solar system do not even come close to representing the true picture of our solar system in size and distance. It will not be necessary to carry the planets past the distance of Jupiter to get this point across to them.

6. Some Stars Are Larger than the Sun (Demonstration and Activity 4-6)

Materials: Two foot diameter globe covered with aluminum foil, large push

SCALE: 2 FT. = 860,000 MILES

ball or three foot diameter globe covered with aluminum foil, and a $\frac{1}{4}$ inch diameter clay ball on a pin.

Procedure: Compare the size of the sun (two foot globe) with that of a star (push ball or large globe) and that of the earth ($\frac{1}{4}$ inch diameter clay ball). Carry the sun 216 feet from the earth. Carry the star past the sun until it appears much smaller than the sun. The scale is again 860,000 miles equals two feet.

Discussion: The farther away the star is from the earth and sun, the smaller it appears. The nearest star is about 26 trillion miles away. This would place the star at a distance of about 60,000,000 feet away, or a distance of approximately 12,000 miles at our scale.

B. THE MOVEMENT OF THE EARTH AND MOON

1. The Earth Is Like a Ball Floating in Space (Demonstration and Activity 2-6)

Materials: Soda straw and ping pong ball.

Procedure: Hold the soda straw in your mouth in a vertical position and hold the ping pong ball over the end of the straw. Blow through the straw and release the ping pong ball. What happens?

Discussion: The ping pong ball will be suspended in a cushion of air and will appear to be floating in the air. This is the way the earth would look if we were to view it from outer space. It would not have the supports at each pole as does the classroom globe.

2. The Earth Is Like a Ball Floating in Space (Demonstration and Activity 2-6)

Materials: Tank type vacuum cleaner and a ping pong ball.

Procedure: Insert the hose of the vacuum cleaner in the discharge end of the tank. This will create a wind instead of a suction. Place the ping pong ball over the end of the hose in an upright position as illustrated in Figure 10.2.

Figure 10.2

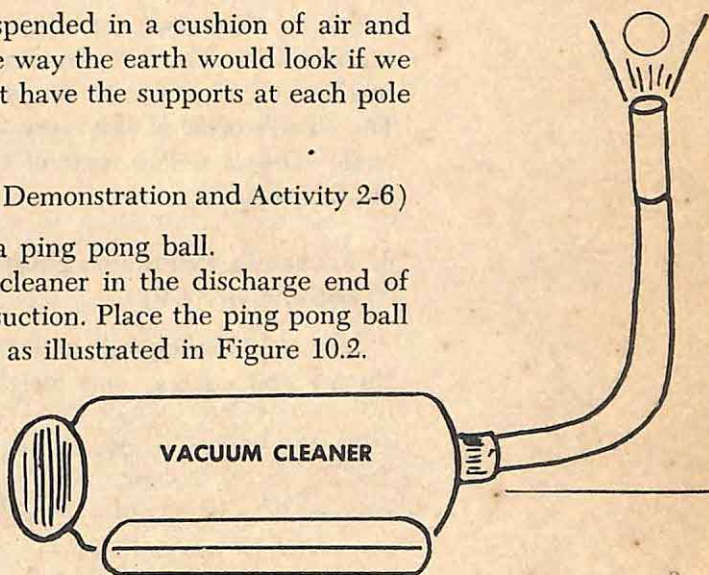
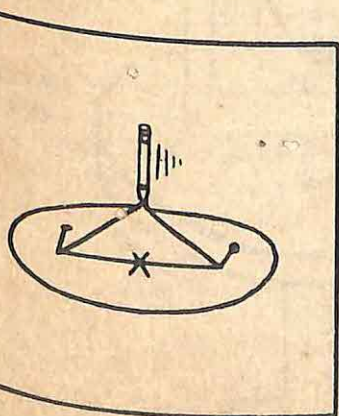
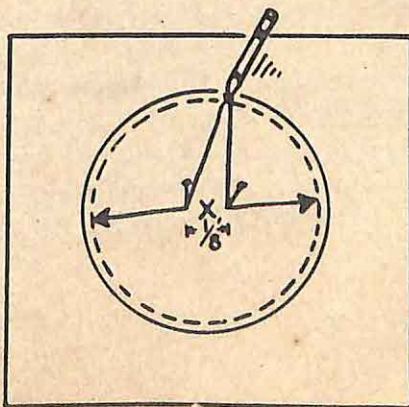


Figure 10.3



(a)



(b)

Discussion: The ping pong ball will be suspended in a cushion of air and will appear to float in air. This is the way the earth would look if we were to view it from outer space. It would have no supports to hold it in space.

3. The Elliptical Path of the Earth (Demonstration and Activity 4-6)

Materials: Two sheets of paper and two sheets of cardboard, each one foot square; two straight pins or nails; a pencil; a length of string one foot long; and thumb tacks.

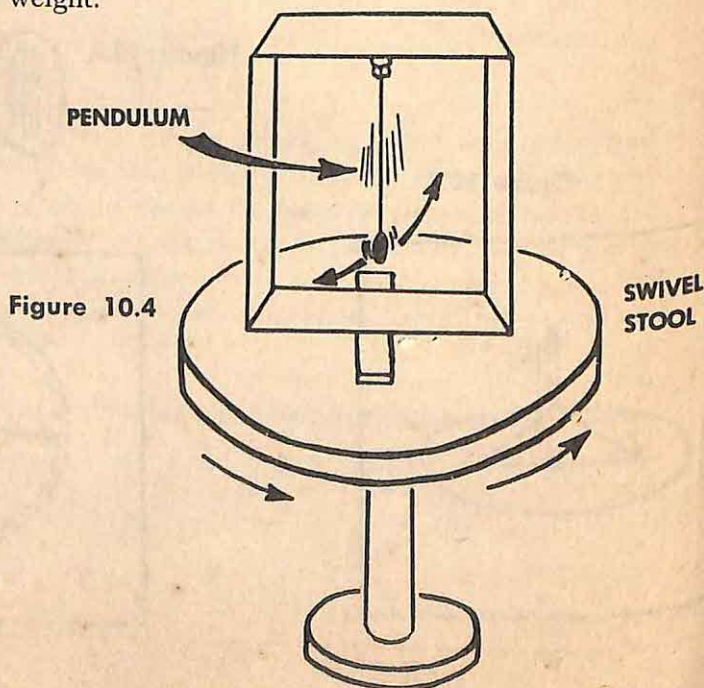
Procedure: Tie the ends of the string together to form a loop. Place a sheet of paper on a cardboard square and fasten it with thumb tacks. Locate the center of the paper by drawing diagonals. Stick the two pins through the paper and into the cardboard, two inches from (and on opposite sides) of the center. These pins will act as pivot points for the loop of string when drawing the ellipse. Place the pencil point inside the loop of string and draw up tightly on the string. Be sure to hold the pencil in a vertical position. Now move the pencil slowly in a circular motion as illustrated in Figure 10.3(a). What you have drawn is an ellipse.

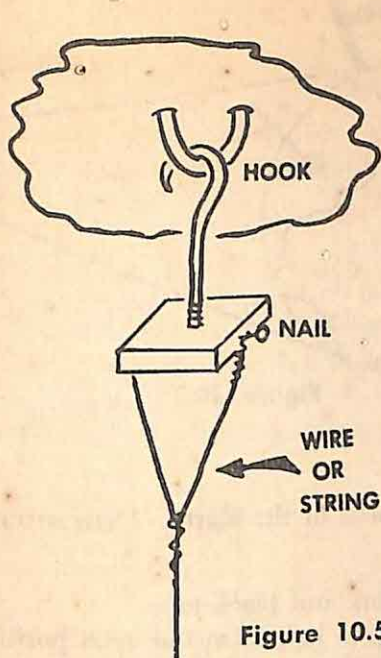
Using another sheet of paper, draw another ellipse with the pins only $\frac{1}{8}$ inch apart or $\frac{1}{16}$ of an inch from each side of the center as illustrated in Figure 10.3(b). Superimpose a true circle over this ellipse by using the same loop of string with a single pin at the center of the paper as the pivot point. How different are these two drawings?

Discussion: The two drawings are almost identical. The ellipse is slightly smaller and its shape is barely elliptical and more nearly represents a circle. The earth's orbit is only very slightly elliptical and may be represented as a circle. This is unlike most of the illustrations drawn to represent the earth's orbital path.

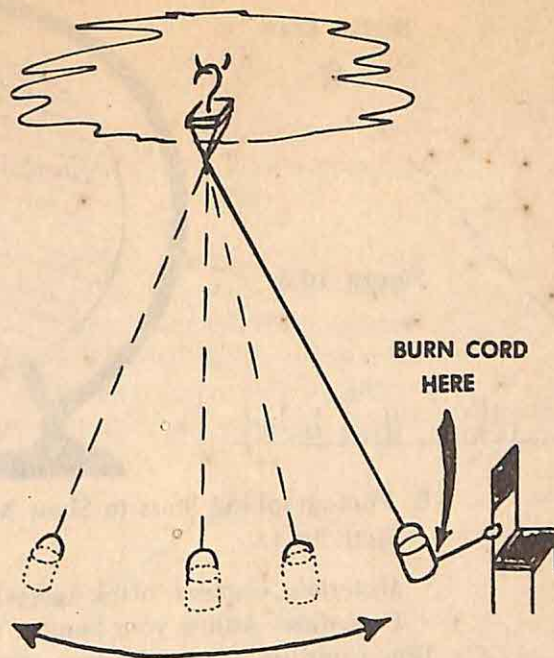
4. Foucault's Pendulum, Showing the Rotation of the Earth (Demonstration and Activity 4-6)

Materials: Revolving stool, flat based wooden bracket about two feet high, thread, and a heavy clay weight.





(a)



(b)

Figure 10.5

Procedure: Place the wooden bracket on the revolving stool. Suspend the weight from the bracket at the end of a string as illustrated in Figure 10.4. Swing the weight and rotate the stool slowly. Observe what happens to the swinging weight or pendulum.

Discussion: The pendulum will swing in a single plane even though the stool rotates. The stool is analogous to a miniature earth which rotates. As it rotates, it moves under the pendulum. The next demonstration will show this action as it occurs on the earth.

5. Foucault's Pendulum, Showing the Rotation of the Earth (Demonstration and Activity 4-6)

Materials: Heavy weight, length of wire long enough to reach from the ceiling to a distance of about $\frac{1}{2}$ inch from the floor, masking tape, string, and matches.

Procedure: Use a steel hook or some other arrangement that you can improvise to attach the wire to the ceiling. Figure 10.5(a) suggests one such arrangement. (The school gym may have a hook arrangement in the ceiling.) Suspend the heavy weight from the wire attached to the ceiling. Tie a three foot length of cord to the weight. Pull the weight about 3 or 4 feet to one side and tie it to a chair or some object in the room as illustrated in Figure 10.5(b). Steady the weight so that it is almost motionless and then burn the cord near the weight. Mark the path of the swinging pendulum with tape or string.

Discussion: The string burns through and the weight begins to swing. We have made a pendulum (Foucault's pendulum). The path of the pendulum will appear to rotate to the right. Actually the pendulum is swinging in the same plane, but the earth is rotating under it. It will take 30 minutes to an hour for any significant movement of the earth to be indicated by the pendulum. The earth rotates 15° per hour.

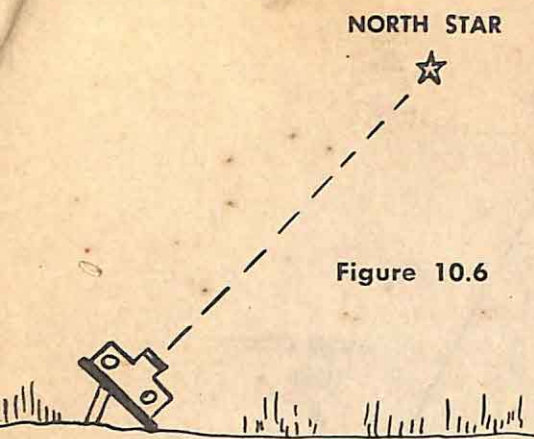


Figure 10.6

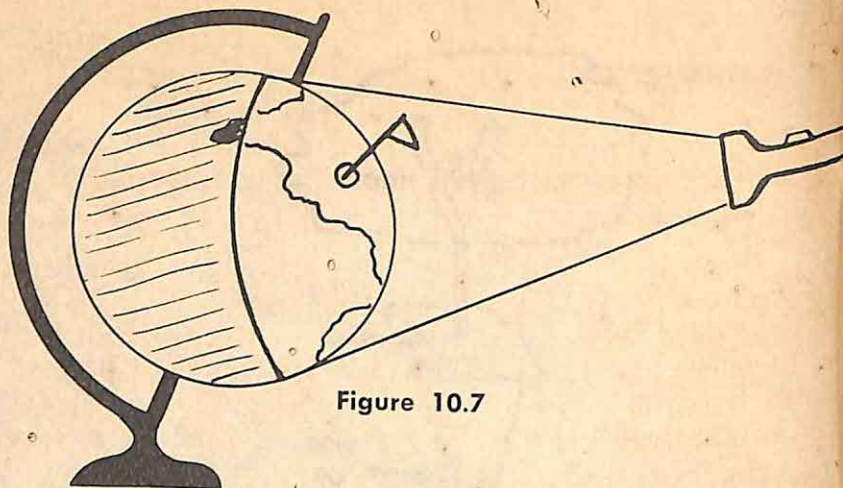


Figure 10.7

6. Photographing Stars to Show Movement of the Earth (Demonstration and Activity 4-6)

Materials: Camera, black and white film, and black tape.

Procedure: Adjust your camera shutter to hold it in the open position for a time exposure. Cover the lens opening with some type of opaque material to shut out the light. Load the film in the camera and turn it to the first exposure number on the film. Carry the camera to an open field which is dark and free of ambient light from street lights and buildings. Locate the North Star and set up your camera at an angle at which it will point at the North Star as illustrated in Figure 10.6. Remove the opaque material from over the lens opening and expose the film for an hour or two. Replace the opaque material over the lens once again and advance the film to the next exposure number. Turn the camera around to face the southern sky. Remove the opaque material from the lens and expose the film for another hour or two. After the entire roll of film has been exposed, have it developed and printed. Be sure to explain to the person processing your film what to expect in the negatives; otherwise he may think the film was under-exposed and not make the prints.

Discussion: The pictures of the northern sky will show trails of light in a circular pattern. The light from the stars exposes the film, revealing the rotation of the earth. The North Star is almost a single spot on the film, and all the other stars appear to be revolving around it. In actuality, the North Star is almost directly above our North Pole. The small circular star trail of the North Star indicates that it is not directly over the North Pole. The star trails of the stars in the southern sky turn out to be straight lines of light. Can you explain why?

7. Day and Night and the Rotation of the Earth (Demonstration 2-6)

Materials: Globe, flashlight, miniature flag, and some clay.

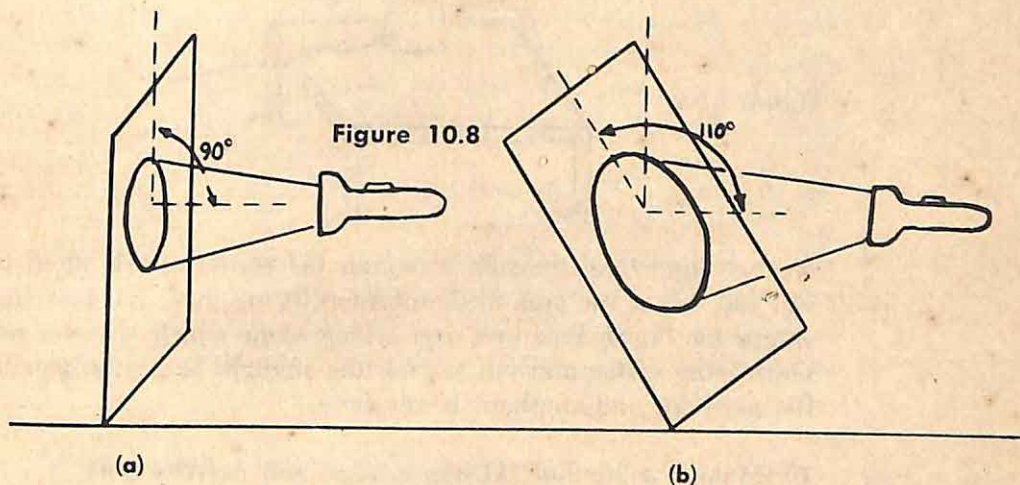
Procedure: Fix the clay to the globe and place the miniature flag pole in an upright position into the clay. Face the flag toward the flashlight and darken the room as well as you can. Now rotate the earth from west to east (counterclockwise) as illustrated in Figure 10.7.

Discussion: When the flag is facing the light, it is daylight. When the earth rotates, the flag moves to the other side of the earth, away from the sun, where it becomes dark. Now we have night.

8. The Slanted Rays of the Sun and Their Effects on the Seasons (Demonstration 4-6)

Materials: Flashlight and a sheet of black construction paper.

Procedure: Hold the sheet of black construction paper in a vertical position and shine the flashlight on it as illustrated in Figure 10.8(a). Holding the flashlight in the same position, decrease the vertical angle of the paper slowly as shown in Figure 10.8(b). Observe the effect on the shape and intensity of the reflected light on the paper as the paper is tilted away from the flashlight.



Discussion: The patch of light becomes larger as the black paper is tilted. The intensity of the light decreases as the light rays from the flashlight spread out over a greater area. In summer in the northern hemisphere the earth's axis is tilted toward the sun because the earth's axis always maintains a fixed direction, and the sun's rays strike the earth at a more direct (nearly vertical) angle. The result is that the rays are more intense. In winter, however, the earth's axis is tilted away from the sun, and its rays are more slanted and less intense. The angle at which the rays strike our region of the earth at this time is obtuse.

9. The Change in Seasons (Demonstration 4-6)

Materials: Electric lamp and a globe.

Procedure: The electric light bulb represents the light rays emitted from the sun. Darken the room as well as you can. Hold the globe by its base and walk slowly around the lamp, keeping the globe about 3 feet from the lamp as illustrated in Figure 10.9. Be sure you retain the constant position of the earth's axis as shown. Observe the effect of the tilt of the earth's axis on the light rays which strike the northern hemisphere of earth; the southern hemisphere.

Discussion: Figure 10.9 shows the position of the earth in relation to the sun at the various seasons of the year. In summer the earth's axis is tilted toward the sun and more of the northern hemisphere, including the North Pole,

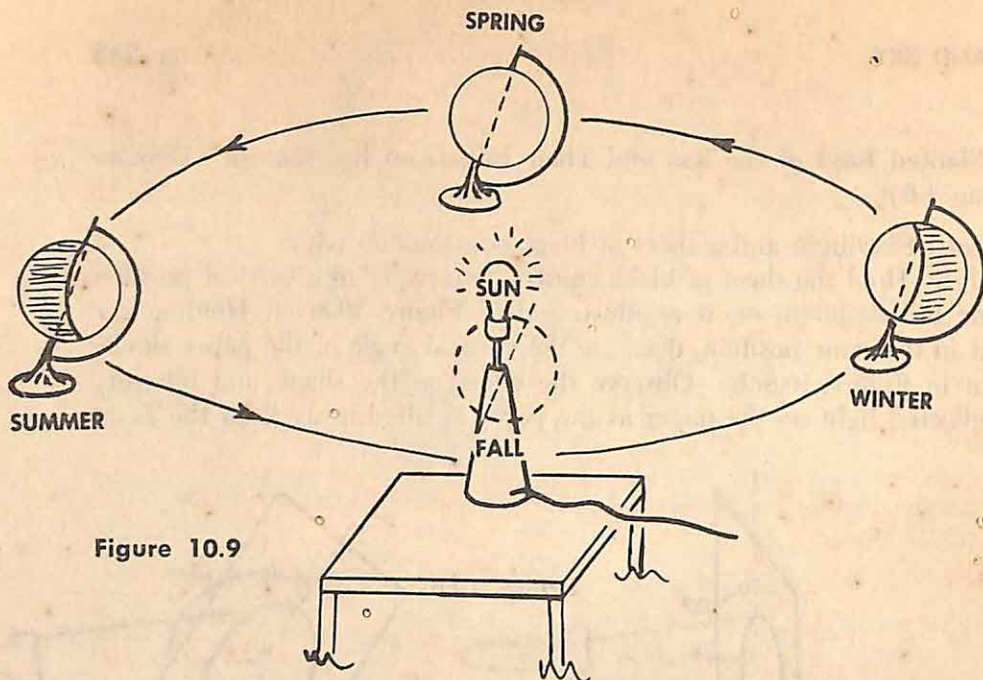


Figure 10.9

receives light from the sun. In winter the earth's axis is tilted away from the sun and less of the area in the northern hemisphere receives sunlight. During winter the North Pole area has a long night which lasts for several months. During the spring and fall seasons the sunlight is evenly distributed between the northern and southern hemisphere.

10. Making a Sundial (Demonstration and Activity 3-6)

Materials: Two sheets of cardboard, crayon, compass, and tape.

Procedure: Cut a round disk about 8 inches in diameter from a sheet of cardboard. Cut a right triangle from a second sheet of cardboard with its base angle equal to the length of a chord drawn horizontally on the disk to represent your latitude. Assemble the disk and triangle as illustrated in Figure 10.10. Place the sundial in the sun with the end marked "north" facing north. A compass will be needed to determine the direction. If the sundial is placed on the window sill in your classroom, mark the positions of the compass on the sill with tape. Observe the shadow as it appears to move. When will it be noon according to "sun time"? Does noon at "sun time" occur at the same time that your classroom clock says noon? At what time did it occur? Does it occur at the same time each day? Keep a record of the time according to your classroom clock when the sundial indicates noon.

Discussion: Noon by sun (solar) time will occur when the shadow of the sundial points directly north. This occurs when the earth rotates to a position where the sun's rays strike the meridian of the earth on which the sundial is located. Noon by the sundial will occur at different times during the year, sometimes coming early and other times coming late. There are four times during the year when noon by sun time (solar time) and watch time (mean solar time) are the same. They occur on or about April 16th, June 16th, September 2nd and December 24th. In between these times noon by sun time occurs before or after noon by watch time. If your records are kept accurately on the

days the sun shines, you can determine the times of the year when sun time is faster or slower than watch time.

The eccentricity of the earth's elliptical orbit is a contributing factor in the change in the length of the solar day. This affects sun time in the following manner: As the earth travels in its orbit around the sun, its distance from the sun changes daily. When the earth is closer to the sun in winter, it travels faster due to the gravitational attraction between earth and sun. As the earth travels faster, it also travels farther each day in its orbital path during this period. This increase in speed in the earth's horizontal path affects the time interval in which a sundial placed on a given meridian of the earth will make one complete rotation and pass through the apparently fixed position of the sun to indicate noon by sun time. In summer the earth is farther away from the sun and its horizontal speed in its elliptical orbit decreases. The net effect is that the earth does not travel as far in its horizontal path each day, and noon by sun time using a sundial comes earlier.

The inclination of the earth on its axis, approximately $23\frac{1}{2}$ degrees, is another contributing factor in the change in the length of the solar day. This is known as the *obliquity effect* and is far too complex to deal with at the elementary school level. The algebraic sum of the *eccentricity effect* and the *obliquity effect* make up the total effect on solar time. For further explanation of these two effects in solar time, consult a basic college textbook in astronomy.

11. Sun Time, East and West (Demonstration 3-6)

Materials: Globe, three miniature sundials, and a spot lamp.

Procedure: Fasten the three miniature sundials vertically on the globe about three inches apart in an east-west direction as illustrated in Figure 10.11. Label the sundial in the center "You." Label the sundial to the east of "You" with an "E" and the one to the west with a "W." Darken the room and switch on the electric lamp so it shines on the globe. Rotate the globe from west to east (counterclockwise), as the earth rotates, so that the three sundials will be exposed to the light. Observe the shadow of each sundial as the globe is rotated. When is it noon by "sun time" on the dial labeled "E"? On the dial labeled "You"? On the one labeled "W"?

Discussion: As the earth moves from west to east, the light from the sun

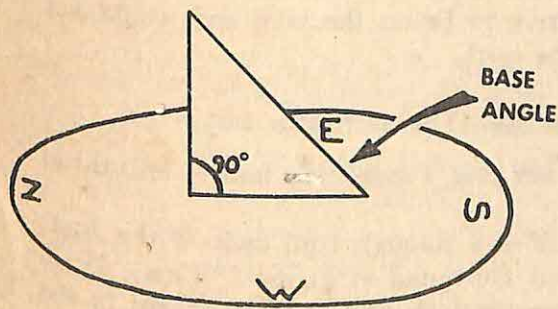
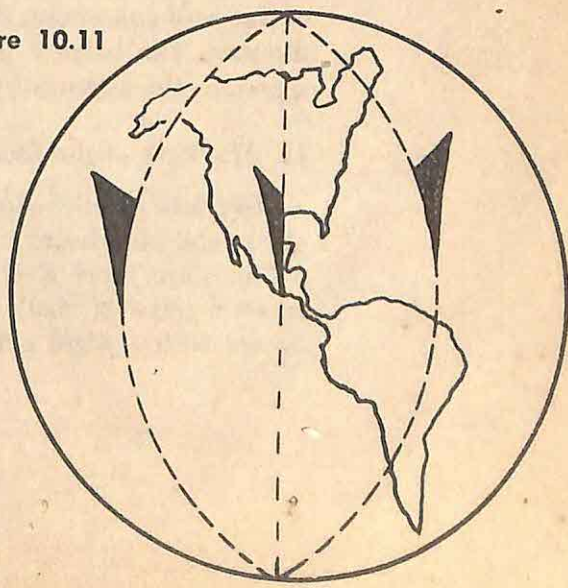


Figure 10.10

Figure 10.11

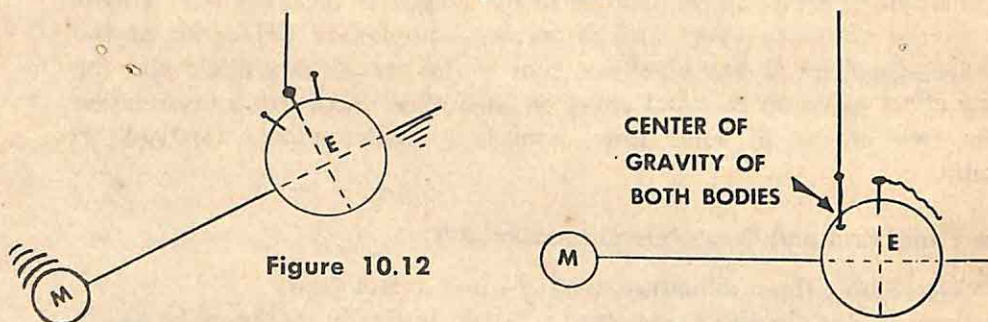


will first cast a shadow on the sundial labeled "E." The shadow of the sundial labeled "E" will point north, indicating noon, before the other two sundials do. When the sundial labeled "You" indicates noon, "E" is past noon and "W" is approaching noon. When the sundial labeled "W" is indicating noon, then "You" and "E" have passed noon. No sundial east or west of "You" would indicate noon at the same time that your sundial indicates noon. This is one of the reasons why we do not use sundials to tell time. Can you think of some other reason why sundials are not used?

12. Balancing the Earth and Moon (Demonstration 4-6)

Materials: Ping pong ball, rubber ball, 12 inch long wire from a coat hanger, straight pin, and some string.

Procedure: The ping pong ball will represent the moon and the rubber ball the earth. Connect the two with the wire and find the point in the earth where the two balance. This can be done with a pin and string inserted into the rubber ball as illustrated in Figure 10.12.



Discussion: The point of balance will not be at the center of the earth (rubber ball) but at a point away from its center. This is the point at which the two bodies revolve around each other.

The moon and earth are balanced by their forces of gravitational attraction. The earth, being 80 times heavier than the moon, has a greater gravitational force. The heavier the body, the greater the force of gravity of that body. This is like two people sitting on a see-saw: a heavy person has to sit closer to the middle of the see-saw in order to balance the lighter person on the other end.

The models used in this demonstration are *not to scale* because the weight of the wire connecting the two would be too great if extended to the proper distance. The balance point would have to be on the wire and would not represent the approximate point on the earth.

13. The Path of the Moon Around the Sun (Demonstration 4-6)

Materials: Small wooden stick 6 inches long, 1 inch wide, and $\frac{1}{2}$ inch thick; chalk; and blackboard.

Procedure: Bore a $\frac{3}{8}$ inch hole half-way through both ends of the stick. Insert a piece of chalk in each hole as illustrated in Figure 10.13(a). Draw an arc with a slight curvature from one end of a 20 foot blackboard to the

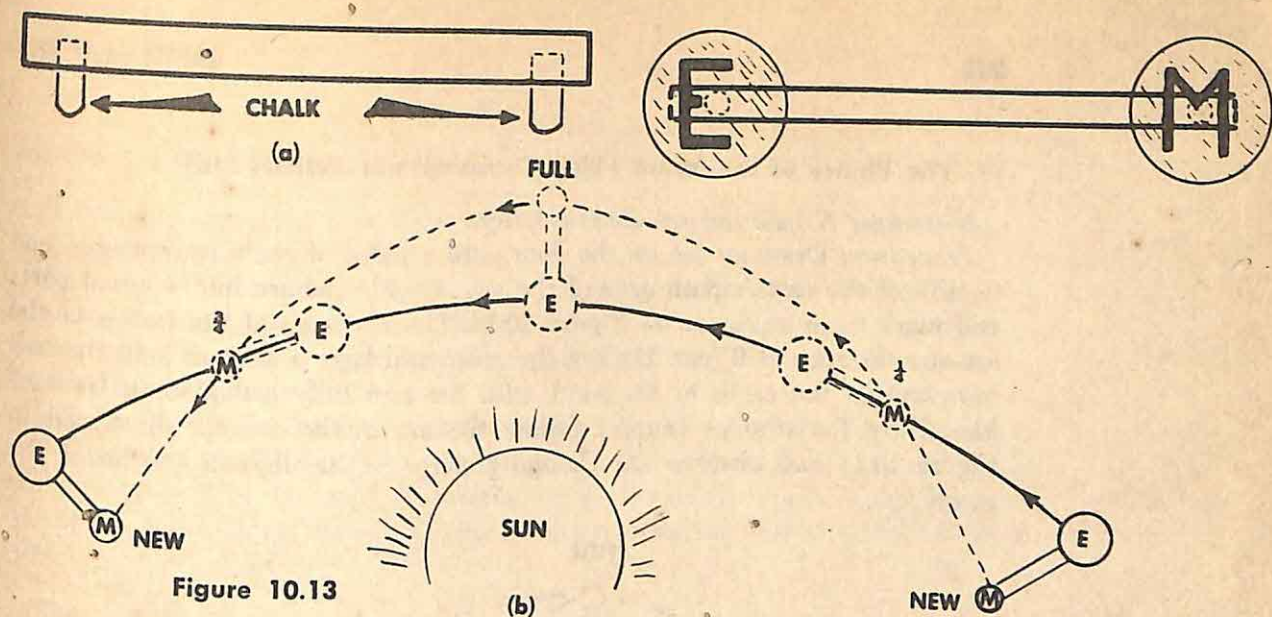


Figure 10.13

other. This will represent one twelfth of the orbit of the earth around the sun. Divide the arc into four equal parts. Each division on the arc will represent about a week's time and one fourth of the complete phase change of the moon, or one fourth of the time from new moon to new moon.

Place models of the earth and moon on the stick as shown and put it against the chalkboard. The chalk under the earth should be placed on the arc. Face the moon in the new moon position, toward the sun as illustrated in Figure 10.13(b). Start moving the earth along the arc while revolving the moon slowly. At the first week marker the moon should be trailing the earth in the earth's path. This is the half moon position. At the two week position (center of the arc) the moon should be on the far side of the earth and away from the sun. This is the full moon position. At the third week marker the moon should be leading the earth in the earth's path. This is the half moon position again. At the fourth week marker the moon will be in the new moon position again. This demonstrates the complete phase change which takes place in $29\frac{1}{2}$ days.

Discussion: The path of the moon is a sinuous path and not a looping one. This is quite different from what we normally visualize the moon's path around the earth and sun to be.

The moon's orbit about the sun is always concave, arched toward the sun. This is due to the fact that the gravitational pull of the sun has a greater influence on the moon than does that of the earth.

To illustrate the orbital path of the moon around the sun to scale, draw a one foot arc with a radius of 2 feet on a large sheet of paper. This arc will represent $\frac{1}{12}$ th of the earth's orbital path around the sun. The scale is 2 feet = 93,000,000 miles. The one foot arc represents the average distance the earth travels in one month (about 48 million miles). Superimpose the orbital path of the moon over that of the earth, starting at the new moon phase and ending up with new moon again at the left end of the arc. According to our scale the moon's path would never be more than $\frac{1}{16}$ of an inch from the earth's path.

14. The Phases of the Moon (Demonstration and Activity 3-6)

Materials: A ball and an electric lamp.

Procedure: Draw an arc on the floor with a piece of chalk to represent one twelfth of the earth's path around the sun. Divide the arc into 4 equal parts and mark them as shown in Figure 10.14. Place a lamp at the radius of the arc at a distance of 6 feet. Darken the room and have a student hold the ball representing the earth in his hand with his arm fully extended in front of him. Have the student (earth) follow the arc in the manner illustrated in Figure 10.14 and observe the changing shape of the lighted section of the moon.

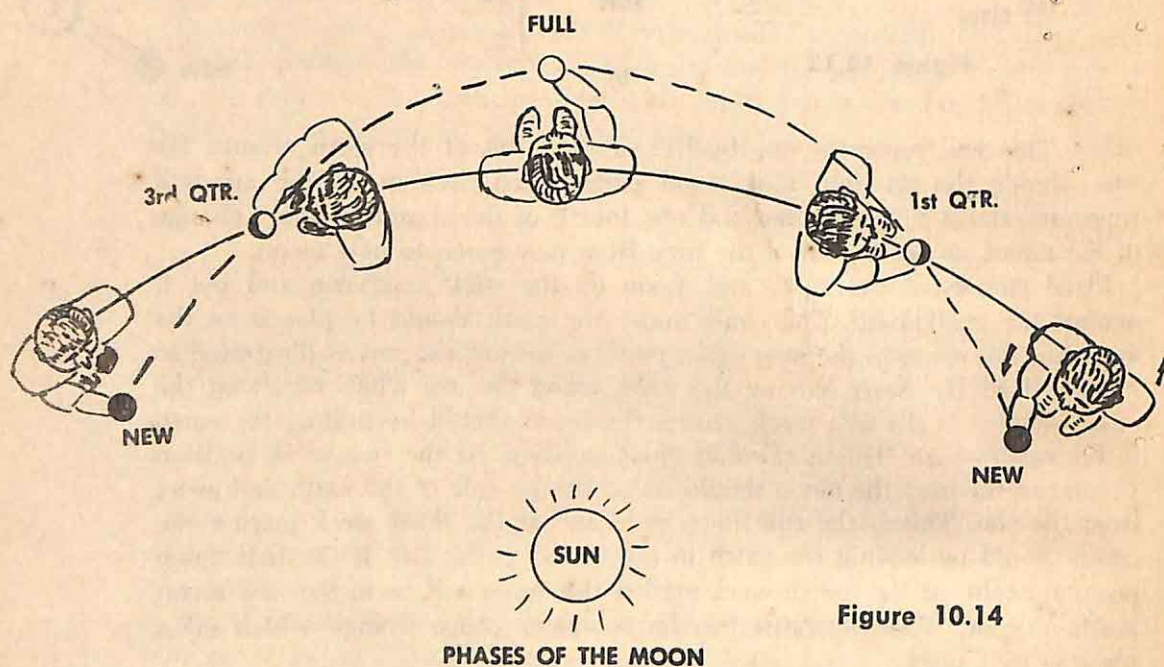


Figure 10.14

Discussion: The phase of the moon can be observed by the student (earth) as he moves along the earth's path. Refer to the preceding demonstration for a more detailed explanation.

As the moon revolves counterclockwise with the earth, we begin to see the first quarter phases of reflected light. The lighted portion of the moon becomes larger until the end of the first week when we see half of the lighted face. This is known as the first quarter because the moon has traveled $\frac{1}{4}$ of the distance for that month. After the second week the moon is in line with the earth and sun, and we have the full moon phase. This is known as the second quarter. (We do not have an eclipse of the moon because the moon's path is 5 degrees higher than the plane of the earth's orbit.) By the end of the third week the moon is again in the half moon stage. During the fourth week the moon phases go from half to quarter to new moon where it cannot be seen again. The cycle then starts over again.

15. We See Only One Side of the Moon (Demonstration 4-6)

Materials: Ping pong ball, a rubber ball, coat hanger wire 12 inches long, a straight pin, and some thread.

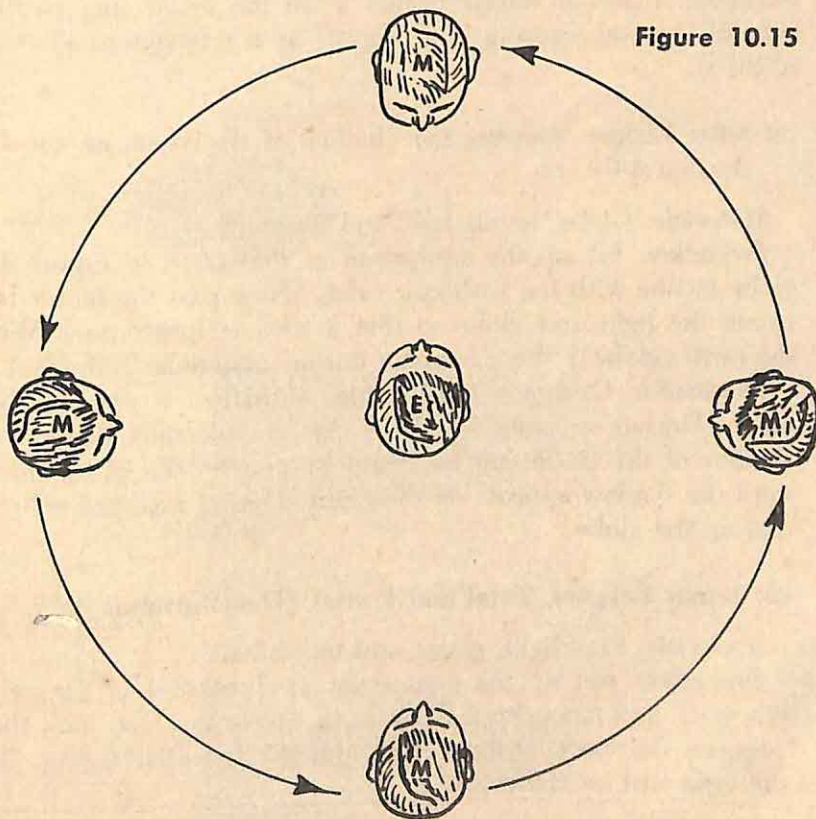
Procedure: Balance the earth and moon as suggested in Figure 10.12. Draw an arrow on the ping pong ball (moon). Slowly revolve the earth and moon around their common center and observe the position of the arrow on the ping pong ball (moon).

Discussion: As the moon and earth revolve, the arrow on the moon makes one complete turn. This represents one rotation of the moon on its axis. As the moon revolves with the earth, its rotation on its axis is at a speed which keeps one side always facing the earth. This is why we can see only one side of the moon from the earth.

16. We See Only One Side of the Moon (Demonstration and Activity 4-6)

Materials: Two students.

Procedure: Have the two students take their places as illustrated in Figure 10.15. One student will be the moon and the other student the earth. Have the moon move counterclockwise around the earth, making sure he faces the earth at all times. How many rotations does the moon make after it has completed one trip around the earth?

**Figure 10.15**

Discussion: The moon will rotate once as it travels around the earth. The student playing the moon will see all parts of the room and make only one complete turn as shown in Figure 10.15.

17. Solar Eclipses (Demonstration 4-6)

Materials: Flashlight, tennis ball, and tape.

Procedure: There are three types of solar eclipses which can be demonstrated: a *total eclipse*, an *annular eclipse*, and a *partial eclipse*. Tape a flashlight to the top of a table and switch on the light. The light from the flashlight represents the light from the sun. The tennis ball will represent the moon as it passes between the sun and the earth (audience). Figure 10.16 illustrates the relative position of the earth, moon, and sun during each type of solar eclipse. Pass the tennis ball (moon) between the audience (people on earth) and the flashlight (sun) at various distances from the light. What effects do you get?

Discussion: The moon is a very small body compared to the sun. However, since the sun is so far away, it appears small, and its light can be blocked by such a small body as the moon. The moon, however, must be at the right distance in order to do this. The closer to the earth, the better is the chance that it will block out the light of the sun in a *total eclipse* as illustrated in Figure 10.16(a). If the moon is too far away from the earth, it will be too small to completely block the light from the sun, and we will have an *annular eclipse*. In an annular eclipse the moon appears as a dark disk with a rim of light all around it when it is at the center of the sun as illustrated in Figure 10.16(b). A *partial eclipse* occurs when the moon only partially blocks the light of the sun, causing it to appear as a crescent as illustrated in Figure 10.16(c).

18. Solar Eclipse Showing the Shadow of the Moon on the Earth (Demonstration 4-6)

Materials: Globe, tennis ball, and flashlight.

Procedure: Set up the equipment as illustrated in Figure 10.17. Place the globe in line with the flashlight (sun). Now pass the tennis ball (moon) between the light and globe so that a total eclipse occurs. What happens on the earth (globe)? What happens during an annular eclipse? A partial eclipse?

Discussion: During a total eclipse a shadow is cast on the earth by the moon. During an annular eclipse the shadow falls short of the earth. The shadow of the moon can be found by moving the globe closer to the moon until the shadow appears on the globe. During a partial eclipse no shadow is cast on the globe.

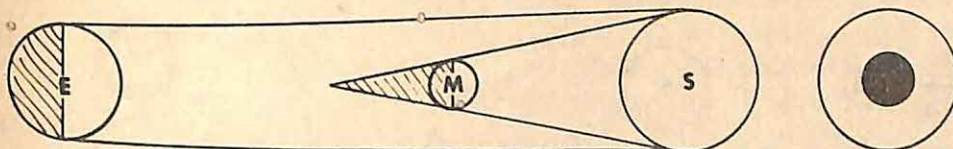
19. Lunar Eclipses, Total and Partial (Demonstration 4-6)

Materials: Flashlight, globe, and tennis ball.

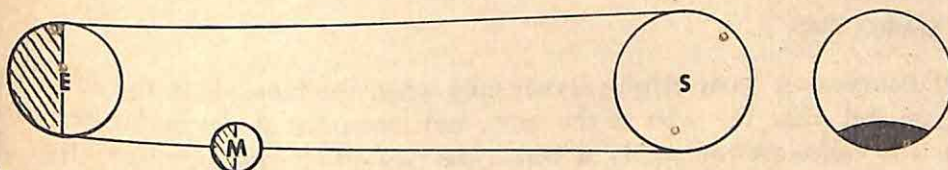
Procedure: Set up the equipment as illustrated in Figure 10.18. Separate the earth and moon by a distance of about five feet. Pass the earth (globe) between the moon (tennis ball) and the sun (flashlight). What happens to the light cast on the moon?



TOTAL ECLIPSE



ANNULAR ECLIPSE



PARTIAL ECLIPSE

Figure 10.16

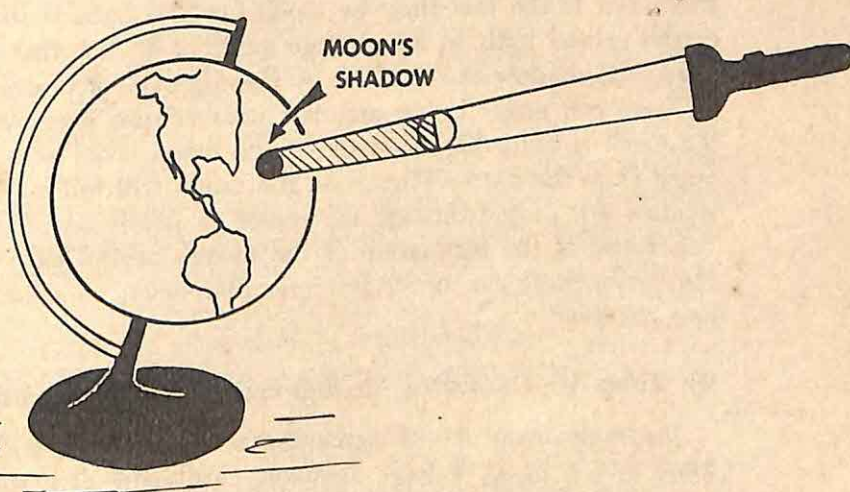
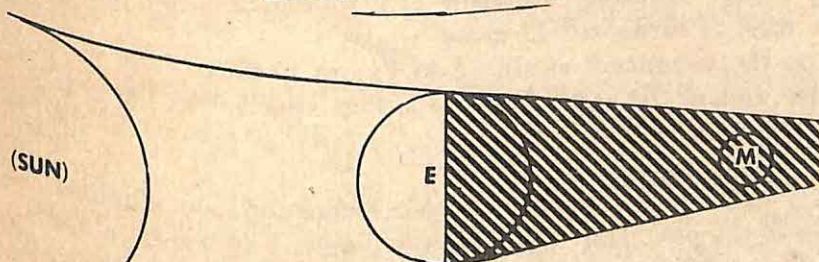
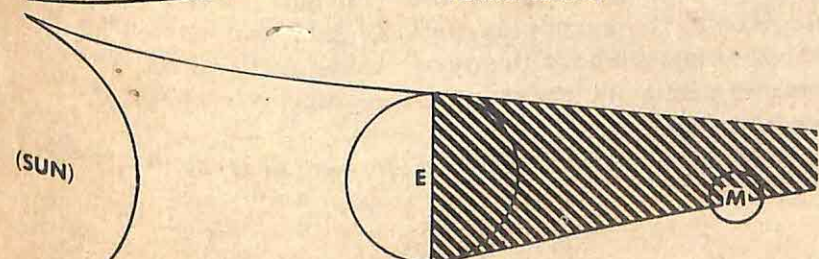


Figure 10.17



TOTAL ECLIPSE



PARTIAL ECLIPSE

Figure 10.18

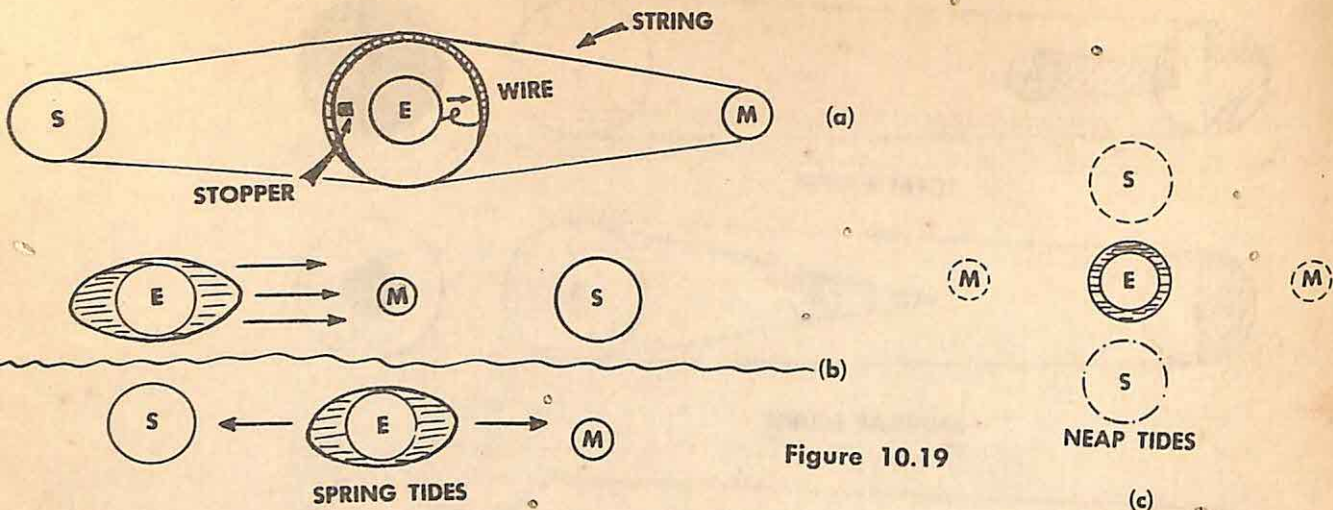


Figure 10.19

Discussion: A lunar eclipse occurs only when the moon is in the full moon phase and when the orbit of the earth and moon are at the *nodes*, or nearly so. The *nodes* are the points at which the two orbits intersect each other. At these times we may have either a partial or total lunar eclipse.

The reason a lunar eclipse does not occur each time the moon is full is attributed to the fact that the moon's orbital path is inclined relative to the earth's orbital path, at an average angle of 5° . For this reason the moon can evade the shadow of the earth by passing over or under it.

There can never be an annular lunar eclipse because the shadow cast by the earth is twice the diameter of the moon, even at its farthest orbital distance from the earth. Therefore, the moon will fall completely in the earth's shadow if it passed through the center, or nearly so, of the shadow.

Because of the inclination of the moon's orbital path in relation to that of the earth, there can never be more than seven lunar eclipses and as few as two per year.

20. Tides Are Caused by the Sun and Moon (Demonstration 4-6)

Materials: Strip of wire screening about one inch wide and 24 inches long bent into a hoop, 4 inch diameter cardboard disk to represent the earth, some string, and a sheet of cardboard 12 inches square.

Procedure: Set up the equipment as shown in Figure 10.19(a). The wire represents the water around the earth. Pull the strings attached to the wire on one side. This represents the pull of the moon's force of gravity on the water of the earth. What happens?

Discussion: As the wire is pulled, the hoop becomes more and more elliptical, bulging on the side of the pull. This represents the piling up of water on one side of the earth due to the moon's gravitational pull. As the wire is pulled further, the string attached to the earth becomes taut and the earth begins to move due to the force of the moon's gravitational field; the earth itself is attracted by and tends to move toward the moon. As the earth moves toward the moon, it moves away from the water on the opposite side of the earth, leaving a pile of water behind.

The water that piles up to cause high tides on two sides of the world

comes from the areas adjacent to the bulges of water. These areas are having low tide. This can be represented by the flattening of the wire in the demonstration.

There are two types of tides: *spring tides* and *neap tides*. *Spring tides* occur when the moon, sun, and earth are in a line as shown in Figure 10.19(b). Spring tides occur during new and full moon phases, which means they occur twice a month. The word spring refers to "springing up" of water and not to the season of the year. These spring tides cause extreme changes in water depth, for example, from 10 to 70 feet in the Bay of Fundy in Nova Scotia, Canada.

There are two times during the month when we have what are called *neap tides*. These occur during the half moon phases (1st and 3rd quarter) and the change in height of the water is very slight. Neap tides occur when the moon and sun are in the positions shown in Figure 10.19(c).

21. Tides Balance the Earth (Demonstration 4-6)

Materials: A toy top and modeling clay.

Procedure: Spin the top and observe that it may wobble slightly. Place a piece of clay on one side of the top as illustrated in Figure 10.20 and spin it again. What happens? Place an equal amount of clay opposite the first piece of clay and spin it again. What happens now?

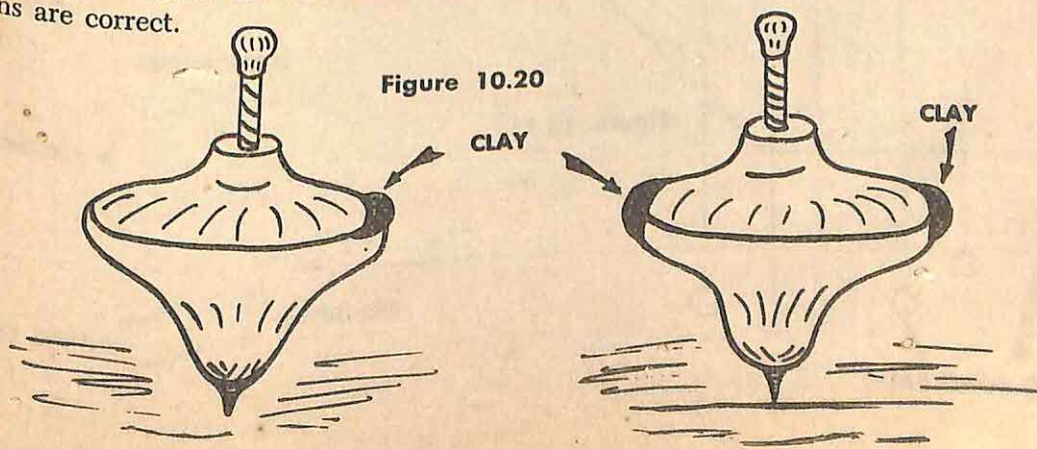
Discussion: The top will wobble quite noticeably with one piece of clay stuck to it. When the second piece of clay of equal weight is placed opposite the first, the two will balance each other, and the spinning top will not wobble.

The earth is revolving—with the moon—around a common center, which is not in the center of the earth but is located inside the earth toward the side near the moon. This would tend to pile the water up on the opposite side of the earth away from the moon due to centrifugal force. This action contributes to the balancing of the earth to prevent it from wobbling.

22. Making a Moon Calendar (Activity 3-6)

Materials: Sheet of white or gray construction paper 18 by 24 inches and a crayon.

Procedure: Draw a calendar for a month and write in the days of the week at the top of the paper and the dates for each day of the month. Observe the moon for two weeks (14 days) and draw in the shape of the moon as it is observed each day. After 14 days of observation, predict the shape of the moon for the remainder of the month and fill in the other days with these drawings. Continue to observe the moon each night and see if your predictions are correct.



Discussion: The phases of the moon follow a definite pattern (which can be predicted after 14 days of observation). If the observations start at the half moon phase, the pattern may be correctly predicted by some students after seven or eight days.

C. THE STARS IN THE SKY

1. Constellations Seen Through Holes in Tin Cans and Cardboard Boxes (Demonstration and Activity K-6)

Materials: Several tin cans or small cardboard boxes.

Procedure: Punch holes in the bottoms of empty tin cans or cardboard boxes in the patterns of various constellations. Hold the tin cans or boxes up to the light. What do you see?

Discussion: Light shining through the holes will resemble the stars in the sky as they appear in the constellations. This is a lead up activity for learning to locate the stars and study other aspects of astronomy.

2. An Umbrella Celestial Sphere (Demonstration and Activity 2-6)

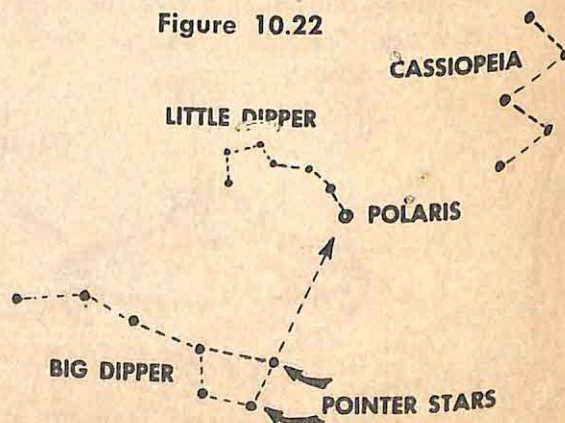
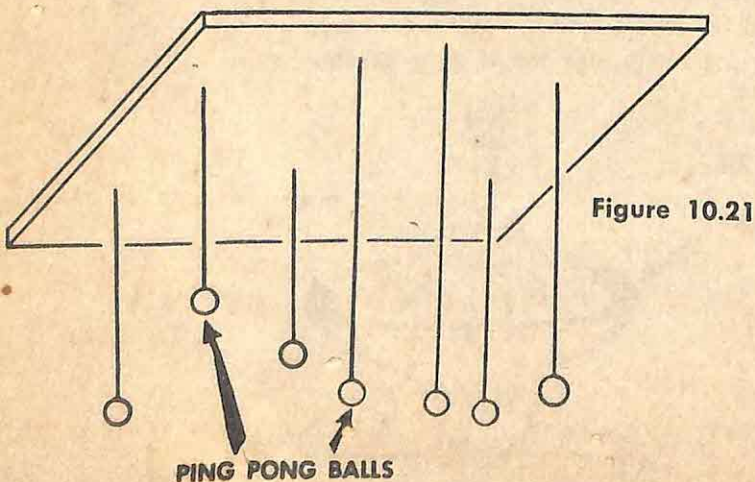
Materials: Umbrella, plainsphere (starfinder), white paper, and paste.

Procedure: Using a plainsphere (starfinder), locate the constellations as they would appear in the sky around Polaris (North Star). Establish the location of Polaris at the center post in your umbrella. Using Polaris as the center of your celestial sphere, establish the location of the other constellations as they would appear to you in the sky. Cut out stars from white paper and paste them to the inside of the umbrella in their proper locations.

Discussion: The umbrella celestial sphere will not be large enough to hold all the major constellations shown on your plainsphere, but a good study can be made of the most prominent ones. Your umbrella can then be taken out-of-doors at night, oriented with the stars in the sky, and used as an aid in locating them in the heavens. Bring a flashlight with you to light up your umbrella celestial sphere.

3. Constellations in Three Dimensions (Demonstration 3-6)

Materials: Seven ping pong balls, rope, thread, and a board about 2 by 4 feet.



Procedure: Using rope, suspend a board from the ceiling so that the flat surface is parallel to and about 6 feet above the floor. Hang the ping pong balls from the board with thread in the pattern of the big dipper as illustrated in Figure 10.21. Make the pattern three dimensional.

Discussion: The stars are not all at the same distance from the earth as they appear to us to be. We can only view them in the sky from one side. The great distance does not allow us to see which stars are closer and which are farther away.

4. Locating the Stars (Activity 4-6)

Materials: Plainsphere and flashlight.

Procedure: A plainsphere is a device used to locate the stars in the heavens. It can be set up for any hour of the day or day of the year. Follow the directions printed on the plainsphere to properly locate the stars and constellations.

There are several "keys" to the constellations. Two of these are the "Big Dipper" and "Polaris" (the North Star). Refer to the illustration in Figure 10.22 to identify the Big Dipper if you do not already know what it looks like. The Big Dipper provides the *pointer stars* which will help you locate Polaris and the *Little Dipper* of which Polaris is a part. From this point the constellation called *Cassiopeia* or the *queen's chair* (sometimes referred to as the "W") can also be located.

Discussion: With each constellation you find, the door is opened up to locating others. Reading about how the constellations got their names and how they have been used for navigation by sailors and overland travelers for many centuries will lead to many interesting classroom projects. Your students might want to investigate how pilots use the stars for navigation and the significance of star navigation in the space program. The potential studies are unlimited in scope.

5. Seeing Sun Spots (Demonstration and Activity 3-6)

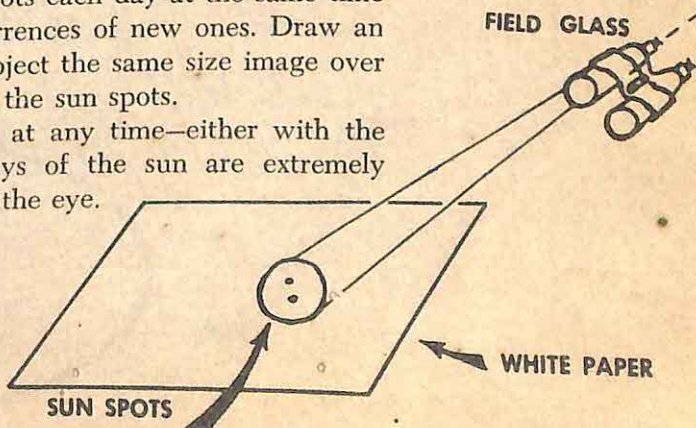
Materials: Refracting telescope or field glasses and a sheet of white paper.

Procedure: Direct a refracting telescope or one side of a pair of field glasses toward the sun so that the light rays are projected onto a sheet of white paper as illustrated in Figure 10.23. What do you observe?

Discussion: An image of the sun will be projected onto the white paper, revealing the sun spots which will appear as dark areas on the light surface of the sun. Check your daily newspapers for information concerning the periods of sun spot activity. Observe the sun spots each day at the same time and look for indications of movements or occurrences of new ones. Draw an outline of the sun's image on the paper and project the same size image over it each day, plotting changes in the position of the sun spots.

Warning: Do not look directly into the sun at any time—either with the naked eye, field glasses, or telescope. The rays of the sun are extremely dangerous and can cause permanent damage to the eye.

Figure 10.23



XI



The Earth: Its Structure and How It Changes

This chapter is concerned with the structure of the earth itself with the greater emphasis being on that part of the earth which houses man and the other living things, known as the crust.

The bulk of the demonstrations and activities are devoted to the study of how the earth's crust is built up and worn down, showing the effects of volcanic action, earthquakes, and weathering.

A. THE STRUCTURE OF THE EARTH

1. The Layers of the Earth (Demonstration 3-6)

Materials: Hard-boiled egg.

Procedure: Cut a hard-boiled egg in half without removing the shell as illustrated in Figure 11.1. Display the cross-section of the egg and draw an analogy between its layers and those of the earth.

Discussion: The yolk of the egg represents the *core* or *inner zone* of the earth, which is believed to be about 4,000 miles in diameter and made up of molten nickel and iron. The white of the egg represents the *intermediate zone*, which is about 2,000 miles thick and is believed to be composed of hot

Figure 11.1

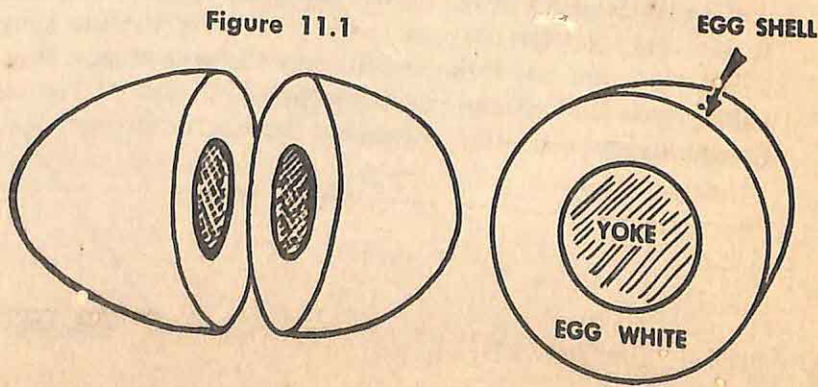
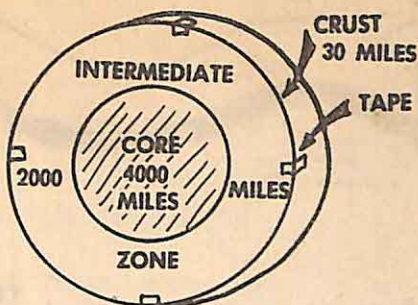
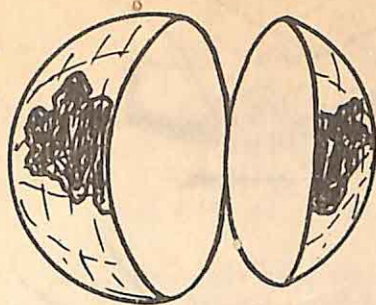


Figure 11.2



rock of a plastic-like consistency. The shell of the egg represents the *crust* of the earth, which ranges in thickness from a few miles to 30 miles. This is the layer on which we live.

2. The Layers of the Earth (Demonstration 3-6)

Materials: Plastic relief globe, a sheet of lightweight cardboard (chip board), and tape.

Procedure: Separate the plastic relief globe at the center seam into two hemispheres as illustrated in Figure 11.2. Cut out a cardboard disk with the same diameter as that of the globe. Draw in the layers of the earth to scale (1 inch = 2000 miles) on the cardboard disk and attach it to the globe with tape as shown.

Discussion: The earth is about 8,000 miles in diameter. The *inner core* is believed to be about 4,000 miles in diameter and made up of molten nickel and iron. The *intermediate zone* extends about another 2,000 miles out from the center of the earth beyond the core and is believed to be made up of the same elements as rock but in a hot plastic-like consistency. The outer layer is known as the *crust*, the thickness of which ranges from a few miles to 30 miles.

B. THE BUILDING UP OF THE EARTH'S CRUST

1. The Effects of the Shrinking and Expanding of the Earth Upon Its Crust (Demonstration and Activity 3-6)

Materials: Large round balloon, sawdust, and wheat paste.

Procedure: Inflate a balloon until it is firm; then knot the end to prevent the air from escaping. Smear some wheat paste over the balloon's surface. Dip it in sawdust until the entire surface is covered and allow it to dry.

When the sawdust firmly adheres to the balloon, untie the nozzle and release the air slowly, observing the balloon's sawdust surface. Blow up the balloon slowly and again observe the sawdust surface.

Discussion: The sawdust surface of the balloon represents the crust of the earth. One theory which attempts to explain the formation of mountains and valleys is the theory of the "shrinking earth." This shrinking is perhaps caused by the cooling of the earth's interior. As the air is released from the balloon, it shrinks in size, causing the sawdust surface to "shrivel up" into mountains and valleys. As the balloon is again inflated, its sawdust surface expands and breaks apart, causing cracks and crevices. This action demonstrates the expansion and contraction theories of the development of the earth's crust and how it changes.

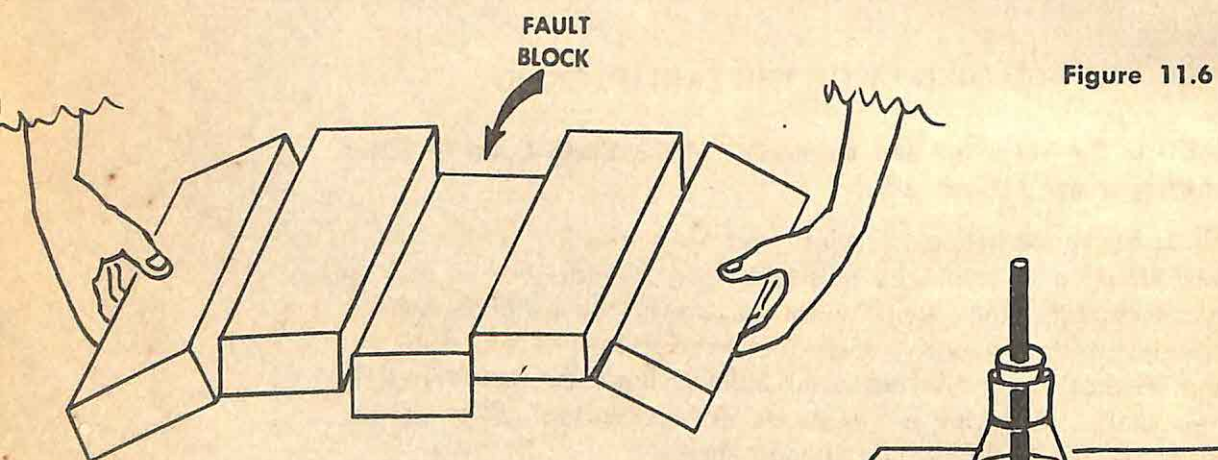
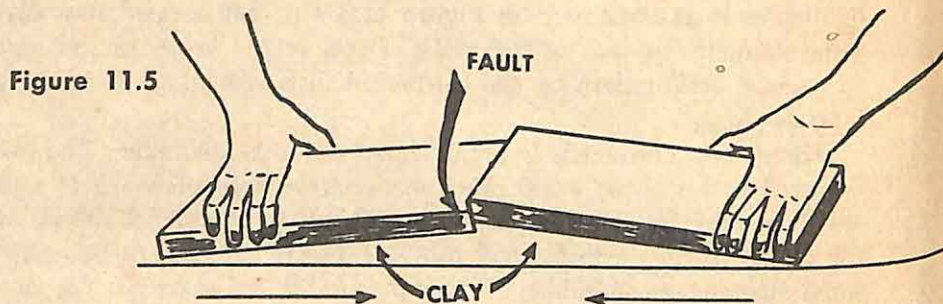
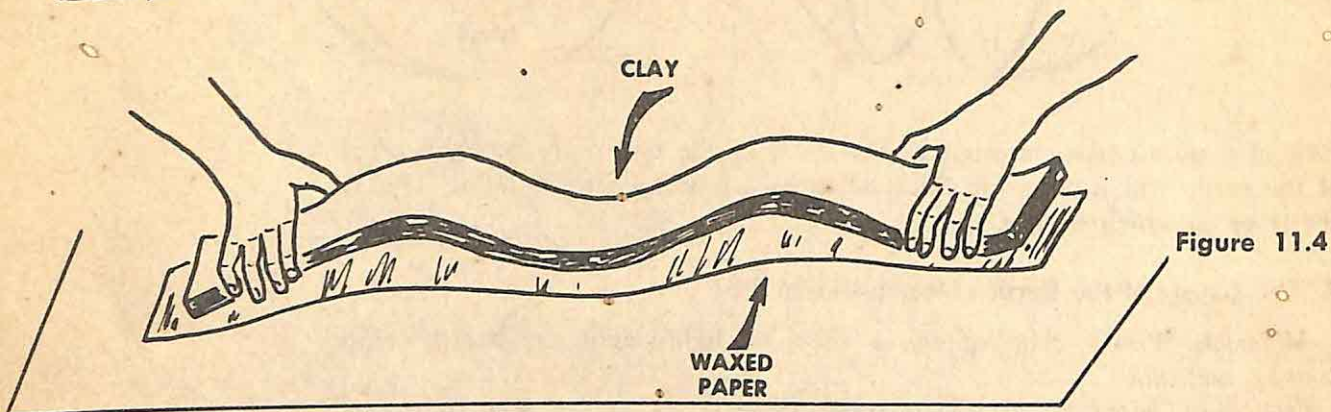
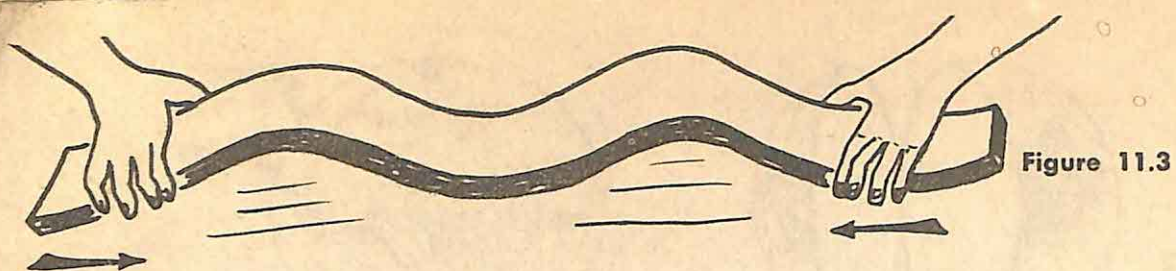
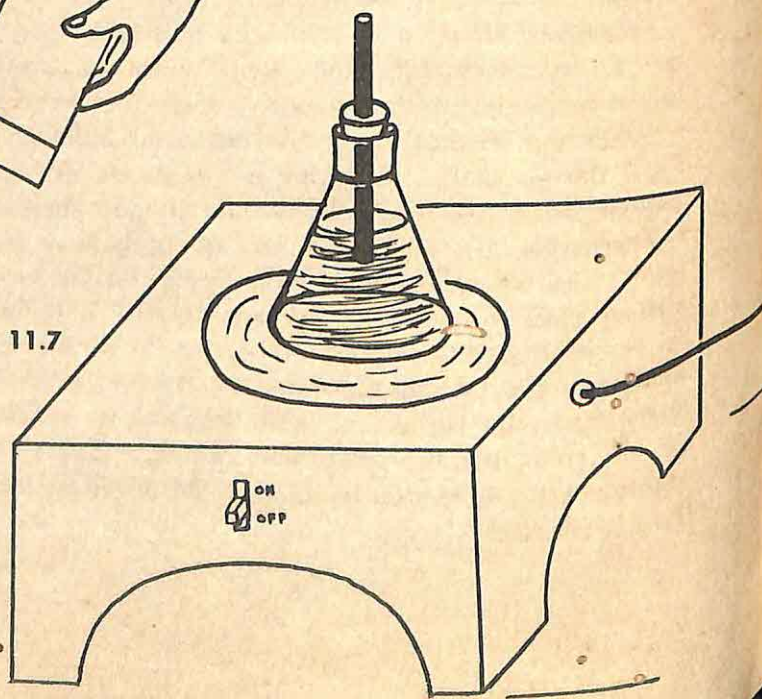


Figure 11.7



2. The Formation of Folded Mountains (Demonstration 4-6)

Materials: Strip of paper 4 by 12 inches.

Procedure: Place the paper flat on a table top and push the ends together as illustrated in Figure 11.3.

Discussion: As the paper's ends are pushed together, it forms one or more bulges similar to tiny hills. This process is analogous to the formation of mountains as the earth shrinks, causing the layers of rock in the earth's crust to buckle up into *folded mountains*.

3. The Formation of Folded Mountains (Demonstration 4-6)

Materials: Slab of modeling clay 4 by 12 by $\frac{1}{2}$ inches and waxed paper.

Procedure: Place the slab of modeling clay flat on a desk top on a sheet of waxed paper. Push the ends of the clay together as illustrated in Figure 11.4.

Discussion: As the ends of the slab of clay are pushed together, the clay develops one or more bulges similar to tiny hills. This is analogous to the formation of mountains as the earth shrinks, causing the layers of rock in the earth's crust to buckle up into *folded mountains*.

4. The Formation of Fault Mountains (Demonstration 4-6)

Materials: Slab of modeling clay 4 by 12 by $\frac{1}{2}$ inches and waxed paper.

Procedure: Place the slab of modeling clay on a sheet of waxed paper flat on a desk top. Cut the slab of clay into two parts at the center. Push the ends together slowly as illustrated in Figure 11.5. What happens?

Discussion: As the ends of the slab of clay are pushed together, one half tends to override the other half. When there is a fault (plane of weakness in the earth's crust), *fault mountains* form as the internal pressures of the earth cause the crust to be pushed together and neighboring crystal layers override each other. The formation of fault mountains is similar to that of folded mountains. The only difference is that the fault tends to produce steep mountain sides with sheer cliffs.

5. The Formation of Fault Block Mountains (Demonstration 4-6)

Materials: Five toy blocks 1 by 2 by 6 inches.

Procedure: Set up five toy blocks on a table top as illustrated in Figure 11.6. Apply pressure to the end blocks by pushing them together until the center blocks are forced upward; then release the pressure by pulling the end blocks apart slightly. What happens to the center blocks when the pressure is released slightly?

Discussion: As the two end blocks are pushed together, the blocks between them begin to rise, then drop down between each other as the pressure is released. This action is analogous to the formation of fault block mountains. This usually occurs when there are two parallel planes of weakness in the earth's crust, like those between the toy blocks. The blocks of earth's crust are forced up as the pressure on each side increases. When the pressure is released, the blocks will drop and often form valleys with step sides and sheer cliffs.

6. The Formation of a Volcano (Demonstration 4-6)

Materials: Pyrex flask, one hole rubber stopper, ink, a length of glass tubing, and a hot plate.

Procedure: Set up the equipment as illustrated in Figure 11.7. Fill the pyrex flask with water, adding a few drops of ink for coloring. Insert the one hole rubber stopper with glass tubing into the pyrex flask and place it on the hot plate. Observe what happens to the water as it is heated.

Discussion: As the water is heated, it expands, rises up the glass tubing, and overflows. Volcanoes usually occur where there is a plane of weakness in the earth's crust. The underlying rocks beneath the crust are usually solid but hot. When the pressure of the weight of the earth's crust is released as a result of plane of weakness in the earth's crust, the underlying rock liquefies into a molten rock known as *magma*. The hot magma expands, becomes lighter, rises up through the crack in the earth's crust, and erupts.

7. Making a Seismograph (Activity 4-6)

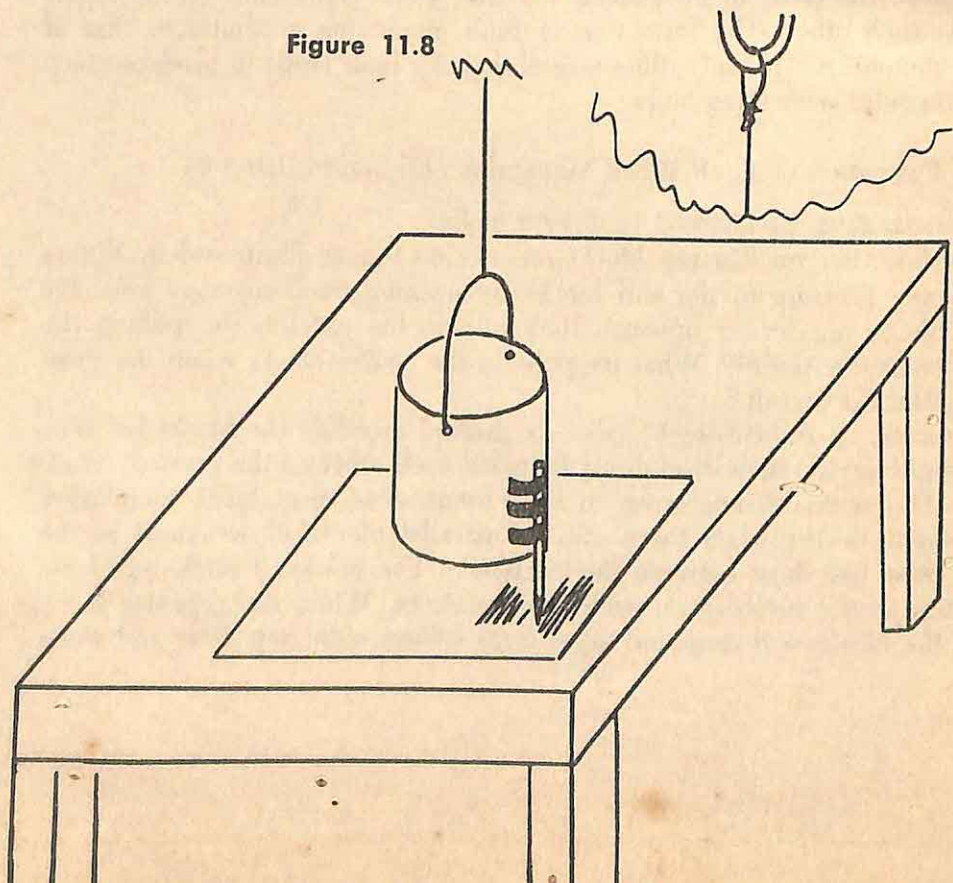
Materials: Tin can, sand, pencil, tape, table, and paper.

Procedure: Suspend a large tin can filled with sand from the ceiling of the classroom. Tape a pencil to the side of the can as illustrated in Figure 11.8. Lower the can until the pencil just touches the table top. Slip a sheet of paper under the pencil point as shown.

If it is impossible to suspend the can from the ceiling of the classroom, suspend it from the cross bar of the playground swing. The only problem here is liable to be the wind.

Move the table gently back and forth in a horizontal plane under the pencil and observe the traces on the paper.

Figure 11.8



Discussion: A seismograph is basically a free-hanging pendulum; its weight holds it steady in the vertical plane. Any horizontal movement of the table under our seismograph will cause the pencil to record a trace on the paper. The greater the movement of the table, the longer the trace. The tracings record the vibrations of the earth during an earthquake. A seismograph can record some of the slightest tremors and give warning of possible earthquakes.

C. THE WEARING DOWN OF THE EARTH'S CRUST

1. The Power of Running Water (Demonstration K-6)

Materials: Garden hose and pile of sand.

Procedure: Attach a garden hose to an outside faucet and direct the stream of water on a pile of sand. What happens to the pile of sand?

Discussion: The pile of sand is worn down and carried off by the force of the running water. Rivers, streams, ocean breakers, and falling rain have the same effect on the land forms of the earth.

2. The Power of Running Water Breaks Up Rocks (Demonstration and Activity K-6)

Materials: Quart jar, masking tape, water, broken chunks of red clay bricks, and a piece of cotton cloth.

Procedure: Wrap some masking tape around the quart jar, then fill the jar $\frac{1}{3}$ full with chunks of red bricks. Completely fill the jar with water and screw on the lid tightly. Pass the jar among the students and have each student shake the jar several times. Be sure they do not shake the jar so violently as to cause the chunks of brick to puncture the glass. After each child has had a turn shaking the jar, empty its contents, filtering it through a cloth. What has happened to the chunks of brick?

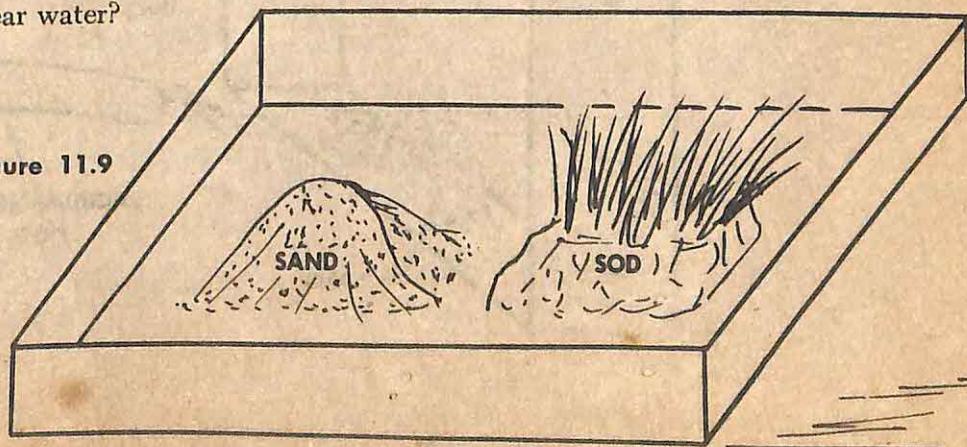
Discussion: The chunks of brick will break up into small pieces as they are churned back and forth in the water. Running water in streams and rivers has the same effect on the rocks which it transports in it. As the rocks strike each other, they are broken into smaller pieces and rounded smooth.

3. Running Water Carries Soil (Demonstration K-6)

Materials: Two jars, each half filled with water, and some soil.

Procedure: Add some soil to one of the jars of water, screw on the lid, and shake well. Pour the now muddy water into the jar with the clear water in it. What happens to the clear water?

Figure 11.9



Discussion: The clear water will become muddy too. When the muddy water was poured into the jar of clear water, the particles of soil were transported with it and mixed with the clear water.

4. Plants Can Prevent Running Water from Eroding the Soil (Demonstration K-6)

Materials: Two glass jars, small pile of sand, some grass sod, porcelain pan, and water.

Procedure: Place a small pile of sand and some grass sod in a porcelain pan as illustrated in Figure 11.9. Fill two glass jars of equal size with water. Pour one jar of water over the pile of sand and the other jar of water over the grass sod. What happens?

Discussion: The pile of sand will wash away quite rapidly, whereas the grass sod will not. The complex root system of the grass holds the soil in place, preventing it from washing away. For this reason plants are essential for flood control and erosion prevention.

5. Wind Can Cause Erosion of Soil (Demonstration 3-6)

Materials: Tank-type vacuum cleaner, small pile of sand, and cardboard box (see Figure 11.10).

Procedure: Insert the hose in the discharge end of a vacuum cleaner so that it blows air out. Direct this stream of air at a pile of sand in a cardboard box. What happens to the pile of sand?

Discussion: The stream of air from the hose will blow the particles of sand around inside the box and erode the pile of sand in much the same manner as does wind.

6. Freezing Water Breaks Up Rocks (Demonstration and Activity 3-6)

Refer to Chapter V, Section C, Activity No. 11.

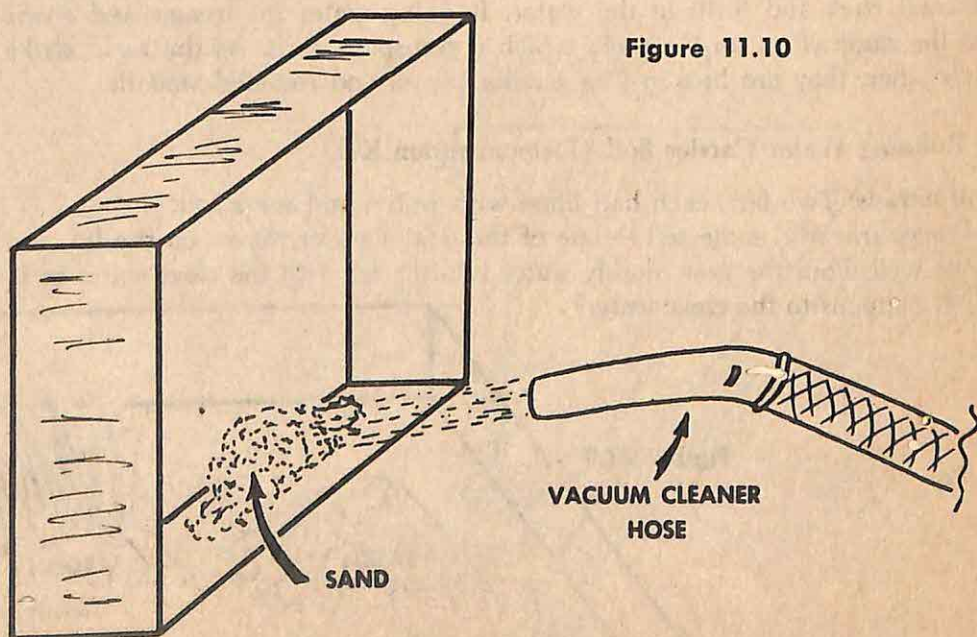


Figure 11.10

XII



Map Making

Closely related to the study of the earth's crust is the study of maps and map making. In reference to the earth's surface, a map is generally defined as a visual representation of the surface of the earth. To a sea captain, however, a visual representation of the surface of the earth in nautical terminology is called a "chart" to distinguish the ocean masses from the land masses. Whether it be called a "map" or a "chart," its purpose is the same: to accurately plot the natural and man-made features of the earth in order to provide safe navigation of modern day ships, planes, automobiles, and space ships.

It becomes quite apparent that, with the constant increase in speeds of the modern modes of transportation, the need for accuracy in making maps and charts of the future becomes a necessity. In the light of these modern improvements of transportation and communication, it also becomes apparent that the children living in this modern age should learn some of the basic fundamentals of map making and map reading. Chapter XII outlines some demonstrations and activities which the classroom teacher can use in a beginning study of maps and map making.

A. TELLING DIRECTION

1. **Making a Needle Compass** (Refer to Chapter VI, Electricity and Magnetism, Section A, Activity No. 21)
2. **Determining Directions in Your Classroom Activity** (Activity 3-6)

Materials: Compass, notebook paper, crayon, and tape.

Procedure: Using a compass, locate the cardinal directions of the compass

(N, E, S, W) of your room. Indicate the cardinal directions of the classroom by placing direction signs on the walls. Capital letters drawn with crayon on sheets of notebook paper taped to the wall will work well.

Discussion: This activity will provide a purposeful experience in using a compass to tell directions and establish the need for knowing directions as a prerequisite to map making.

B. MAKING A MAP

1. Making a Scale Map of Your Classroom (Activity 3-6)

Materials: Sheet of white construction paper or newsprint 18 by 18 inches, pencil, and ruler.

Procedure: Have the children measure the length and width of the classroom, using a foot ruler or yardstick. Record the dimensions as they are measured. Using the dimensions of the classroom, have the children mark off the width of the front of the room on a sheet of paper, starting at the corner of the paper which corresponds, in direction, with that of the room. For every foot measured, mark off $\frac{1}{2}$ inch on the paper as illustrated in Figure 12.1. Using the same scale ($\frac{1}{2}$ inch equals one foot), plot the sides and back of the room on the paper.

Discussion: A scale outline map of the room has been produced. To make the map more complete, measure and draw in the windows, doors, closets, desks, chairs and as many other details as desired. It is important in this activity for the children to work diligently and accurately so that the task becomes somewhat tedious and laborious. The reason for this is: (1) to give them an appreciation of the work involved in careful map making and (2) to give them an appreciation of the simpler and less tedious methods of map making which has evolved through the centuries.

At this point in the study of map making, attention should be focused on the meaning of *scale*. The children can discover the meaning of scale by comparing the size and shape of the map which they made of the classroom with the size and shape of the actual classroom. Ask the children these questions:

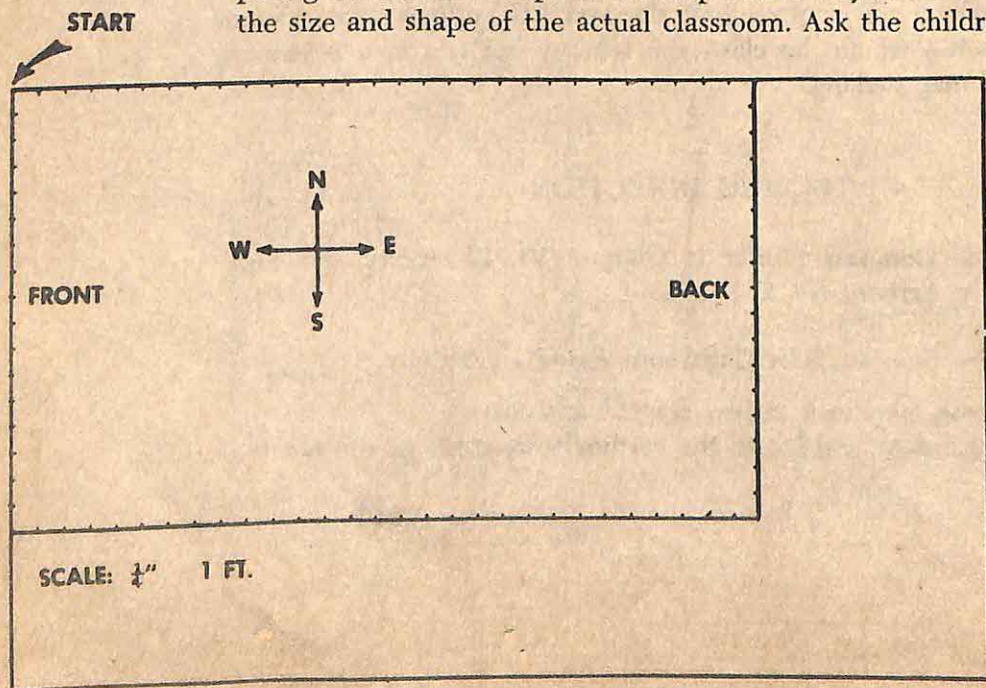


Figure 12.1

Was the size of the classroom changed after you drew it on the sheet of paper? The answer is obviously yes, it has become smaller. Has the shape of the classroom changed as a result of the reduction in size? No, it hasn't. Drawings made to *scale*, then, change in *size* but not in *shape*.

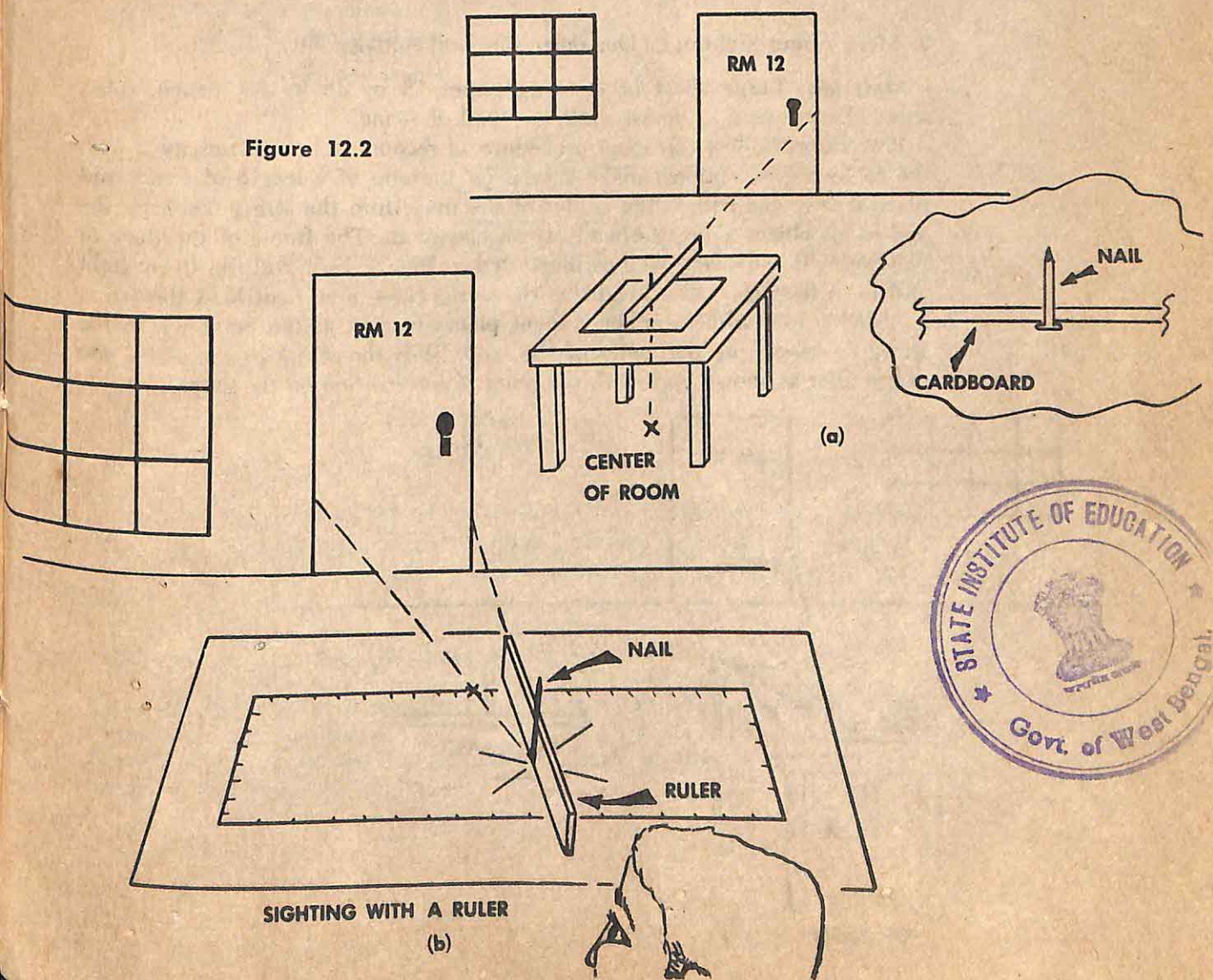
Two scale drawings of the classroom could be made using two different scales for comparison, as an additional activity to show how scale changes size but not shape of the classroom.

2. Making a Scale Map by Taking Sightings (Activity 4.6)

Materials: Large sheet of drawing paper 18 by 18 inches, pencil, ruler, sheet of cardboard, compass, desk, tape, and a nail.

Procedure: Draw a scale map of your classroom at a scale of $\frac{1}{2}$ inch equals one foot as described in Demonstration 1. Tape the map to a sheet of cardboard and locate the center of the map. Insert a nail through the cardboard at the center of the map as illustrated in Figure 12.2(a). Fasten the map to the desk top with tape. Next, find the center of the classroom and mark it on the floor with tape. Place the center of the map over the center of the room as shown in Figure 12.2(a). Orient the map with the classroom by lining up the nail in the center of the map with the corner of the map and the

Figure 12.2



corner of the room by using your eye. Place the ruler on the map with one side touching the nail. Sight or aim along the side of the ruler at an object along the wall of the room. The door frame will do well for a starter. Draw a line from the center of the map to the point where the ruler cuts across the line representing the wall of the classroom. Now sight the other side of the door frame and draw a line as before. The space between the intersection of the two lines represents the width of the door. Measure it on the map, using the scale of one foot equals $\frac{1}{2}$ inch. How does it compare with the actual width of the door? How does it compare with the width of the door on your first map?

Discussion: Many of the objects which are along the walls can be plotted, using the sighting method. These could include the windows, doors, bulletin boards, pencil sharpener, and many others. To find the location of other objects which are not located at the perimeter of the room, a measuring device must be used. The sighting could first be taken to line the object up with the center of the room, and then the distance of the object from the center of the room could be measured and plotted to scale on the map. This process is much more complicated but can be done.

For a further understanding of how sightings are used in making maps, refer to the next activity.

3. More About Sightings (Demonstration and Activity 4-6)

Materials: Large sheet of drawing paper 18 by 18 inches, pencil, ruler, sheet of cardboard, compass desk, and ball of string.

Procedure: Follow the same procedure as recommended in Activity 2 with the following exceptions: make a loop on the end of a length of string and place it over the nail in the center of the map. Run the string out from the nail to an object along the wall of the classroom. The frame of the door or window will work very well as illustrated in Figure 12.3. Pull the string tight and keep it at the same height as the desk. Have a student hold the string at this location while another student places a mark at the point where the string intersects the perimeter of the map. Shift the string to the other side of the door as shown and mark the point of intersection on the map.

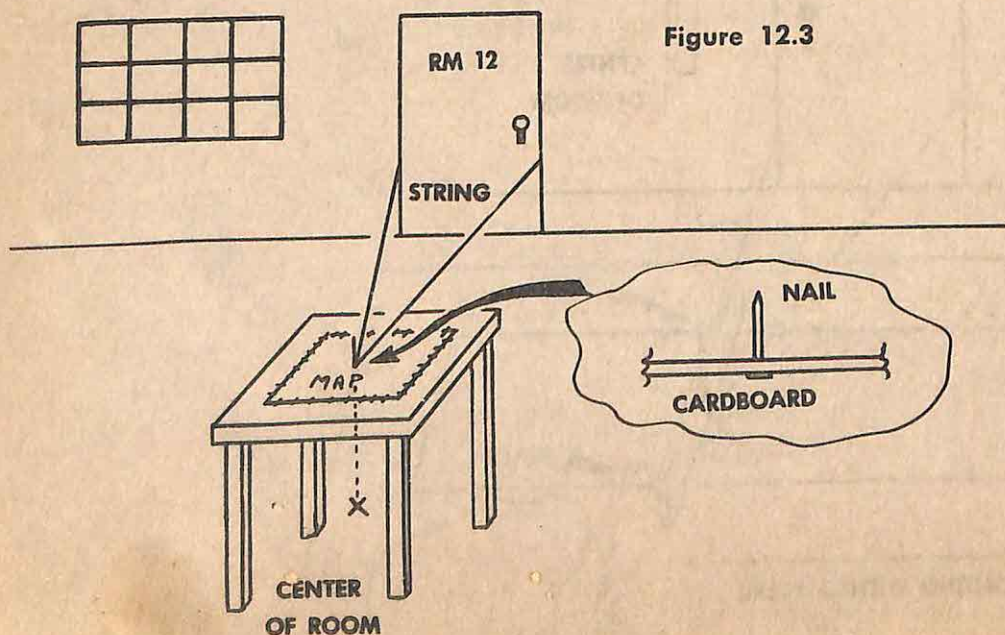


Figure 12.3

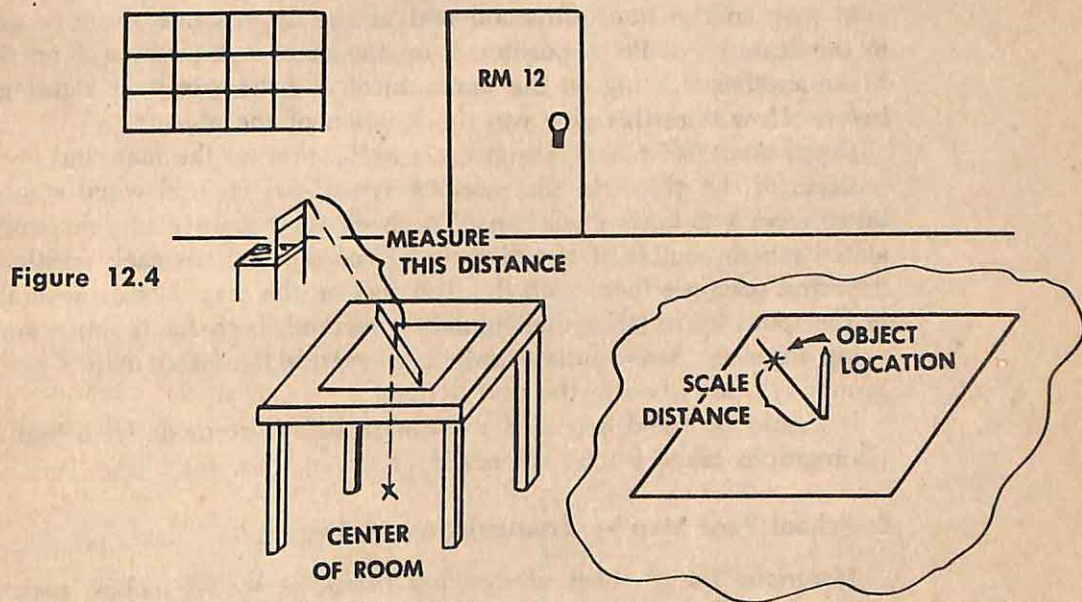
Discussion: The marks on the map where the string crossed the outline of the room will correspond, to scale, to the width of the door in your classroom. Measure it to check your results. Try some other objects along the wall of the classroom. Your eye does the same thing as the string when you make a sighting with the ruler as was done in Demonstration 2.

4. Using Sightings and Measurements to Expand a Map (Demonstration and Activity 4-6)

Materials: Large sheet of drawing paper 18 by 18 inches, pencil, ruler, sheet of cardboard, compass, and desk.

Procedure: Follow the same procedure for setting up the equipment as recommended in Activity 2 of this section.

Figure 12.4 illustrates the procedure for locating objects which are away from the perimeter of the room. First sight the object, in this case a chair, by using the ruler and then draw a line along the ruler from the center of the map to its perimeter. Measure the actual distance from the center of the room to the object. Convert this distance to scale and measure it off on your sighting line from the center of the map outward as shown in Figure 12.4.



Discussion: Determining the exact location of objects within the classroom walls can now be accomplished with great accuracy and ease. This activity could then lead to the next activity which involves map making by *triangulation*.

5. Classroom Map by Triangulation (Activity 4-6)

Materials: Large sheet of drawing paper 18 by 18 inches, pencil, ruler, sheet of cardboard, compass, and desk.

Procedure: Follow the same procedure for setting up the equipment as recommended in Activity 2 (above).

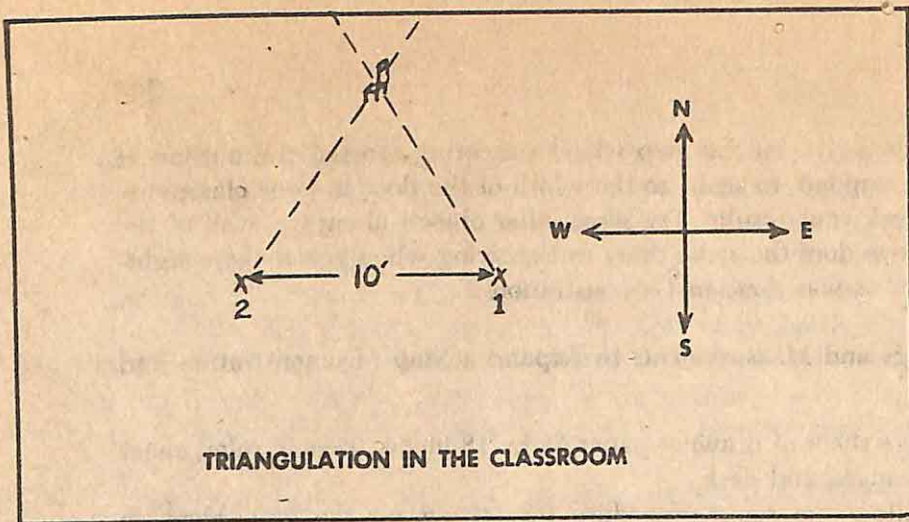


Figure 12.5

Figure 12.5 illustrates the procedure for locating objects which are away from the perimeter of the room by using the *triangulation* method. The center of the room is position 1, and it corresponds with the center of the map. Sight an object from position 1 by using a ruler and draw a line along the ruler from the center to the perimeter of the map. Move the map to a known position about 10 feet in one direction (N, E, S, or W) from the center of the room. Mark this position on the floor as position 2. Indicate position 2 on your map in the same direction and at the appropriate distance according to the scale used. Place position 2 on the map over position 2 on the floor. Make another sighting on the same object and draw in your sighting line as before. How does this give you the location of the object?

Discussion: The two sightings cross each other on the map and give us the position of the object in the room. A triangle is created when sightings are taken from two known positions. To check the accuracy of your work, make actual measurements of the distance of the object from each position on the floor and compare them with the distances on the map. Locate several objects in the room by using the triangulation method, both for practice and to develop accuracy. Now you are ready to go outside to make a map of your school grounds as described in the next activity.

It should be noted here that most maps today are made from high altitude photographs taken from airplanes.

6. School Yard Map by Triangulation (Activity 4-6)

Materials: Large sheet of drawing paper 24 by 28 inches, pencil, ruler, sheet of cardboard, compass, and desk.

Procedure: The equipment set up is the same as for the previous activity using triangulation except that it is to be outside. The accurate use of the compass plays a very important role in making a map outside as well as indoors.

Using a compass, establish the cardinal directions of the school grounds. Indicate these directions on your sheet of drawing paper and orient the paper accordingly. Next, pick out your starting point. The starting position can be at a place on the school grounds which is fixed or at a known *distance* and *direction* from a fixed point. This fixed point could be a tree, a corner of a

building, a sidewalk intersection, or a plaque fixed in the ground. Establishing the starting position is the most important task in triangulation because this will be the reference point for all sightings.

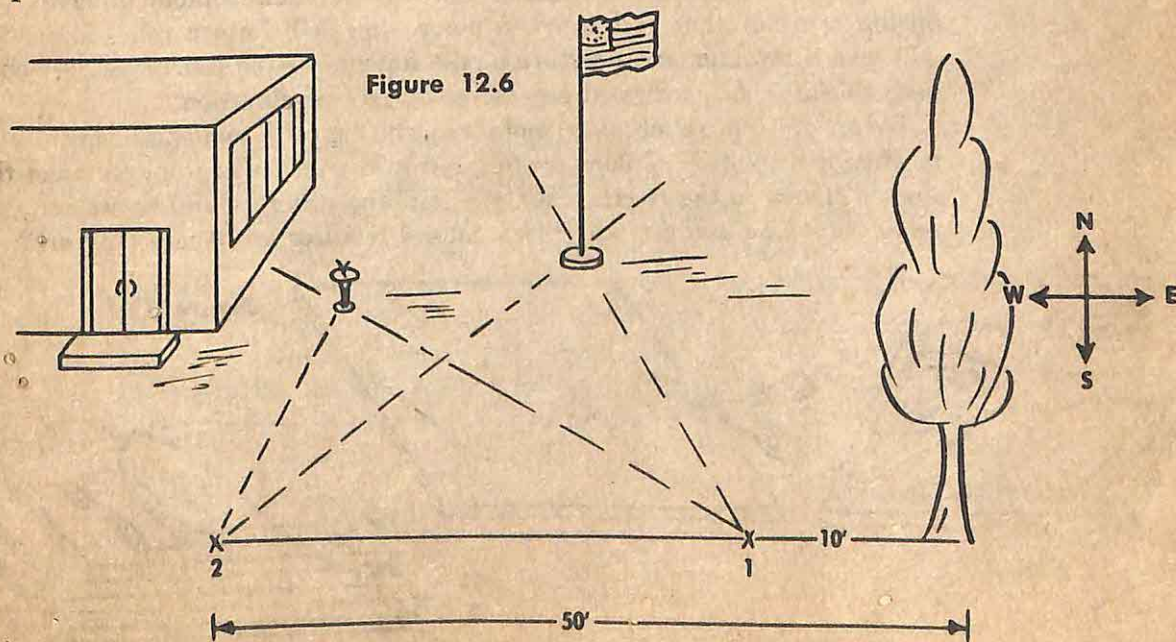
Measure a distance of 10 feet from the base of the tree in a cardinal direction of the compass, N, E, S or W, as illustrated in Figure 12.6. (In the case of Figure 12.6 the direction is west.) Drive a small peg into the ground at this position and call it position 1. Now this information must be transferred to your map. Establishing the position of the fixed tree is easy. All you have to do is place an "X" on the paper in the general area corresponding to its position on the school grounds.

The critical step comes when you establish position 1. Select a scale you desire to use and measure 10 feet in the same direction from the "X" on the paper as you did from the fixed point on the ground (in the case illustrated, west). Place position 1 on the map over position 1 on the ground, orienting the compass directions on the paper with those of the school grounds.

Now take several sightings on various objects from position 1. Figure 12.6 suggests a flag pole and a bird bath. Draw these sightings on your map, making sure to extend the lines far enough. A safe procedure is to extend them to the edge of the paper. You now have half of the job done.

The next critical step comes in establishing position 2. It is done in exactly the same way as it was done in the classroom. Measure about 50 feet from the base of the tree in the same direction as position 1, west as illustrated in Figure 12.6. To be sure your direction is accurate; have a student stand over position 1 and line the student up with the tree by sighting. Draw this position accurately on our map and label it position 2. Place position 2 on your map over position 2 on the ground. Orient the directions on your map with those of the school grounds once again. Sight the flag pole and bird bath as illustrated in Figure 12.6 once again and draw the sight lines of the map as before. Can you see how the flag pole and bird bath in Figure 12.6 were located? You may use any fixed object in the school grounds you desire to take your sightings.

Discussion: The positions of the objects are located where the sighting lines from position 1 and 2 intersect on the map. This method is known as *triangulation*.



In more technical terms, the base of the triangle is the line between positions 1 and 2. This is known as the *base line*. From here almost any visible object can be plotted within the limits imposed by the size of the paper, the scale used, and the distances involved. Distance affects the *acuteness* of the triangle, which in turn affects the accuracy of the plot. The more parallel the two sighting lines become, the more acute the angle of intersection becomes. Extremely *obtuse* triangles can have the same effect on the accuracy of a plot. The children will soon discover this as they work more with triangles. To avoid this situation, at first work from several *base lines* which provide better angles of intersection. Try long base lines and short base lines and see how they affect the plot.

7. Making a Relief Map From a Topographic Map (Activity 4-6)

Materials: Several sheets of corrugated cardboard from a box, a United States Geological Survey map of your area, a straight pin, and some thumb tacks.

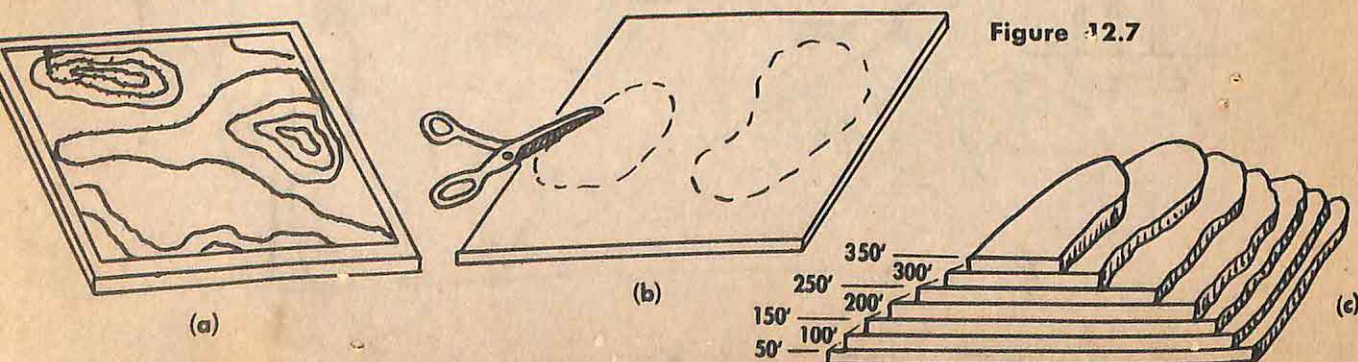
Procedure: Each dark contour line on a topographical map represents an increase in elevation of fifty feet. When the contour lines are close together, they indicate steep hills. When they are far apart, they signify a gently sloping hill or mountain.

Place the map on a sheet of cardboard and secure it in place with a thumb tack at each corner. Pick out a dark brown contour line in the map at the apex of a hill or mountain and prick holes through the map into the cardboard, following the contour line. Space the pin pricks at intervals of $\frac{1}{2}$ to $\frac{1}{4}$ inch apart. After you have completed a closed figure, remove the map and cut the cardboard, following the line made by the pin pricks as shown in Figure 12.7(b).

Follow the same procedure for each successive contour line of lower elevation until you have cut out all the contours on the map and have formed the hills and valleys of your area. Stack the cardboard cut-outs on top of each other with the smaller high elevation cut-outs piled on top of lower elevation cut-outs as illustrated in Figure 12.7(c).

Discussion: With the cardboard cut-outs of each contour interval piled on top of each other and glued in place, they will form a relief map which will give a representative picture of the topography of your area. Remember each thickness of cardboard represents 50 feet of elevation.

To make your relief map more realistic, spread modeling clay, papier-mâché, or a solution of flour, water, and salt over the contour to make them smooth. Draw in the rivers, lakes, streams, and other natural resources on the relief map. Can you see why these natural features are where they are?



XIII



Rockets and Space Travel

The science of rocketry and space travel has literally and figuratively "rocketed" into the foreground of the scientific community of the world. The science of rocketry and space travel has also "rocketed" into the lives of the young children of the world as well. It is from these impressionable youngsters that the future space scientists and astronauts will emerge. It is with these impressionable youngsters of the elementary school age that a study of the basic scientific principles, laws, and theories of this fascinating field of science should begin.

Chapter XIII will incorporate demonstrations and activities with which the classroom teacher and students can experiment as they investigate Sir Isaac Newton's three laws of motion and how they apply to rocket propulsion and the orbiting of satellites.

A. ROCKET PROPULSION

1. Action and Reaction (Demonstration and Activity K-6)

Materials: One balloon.

Procedure: Blow up the balloon, close nozzle with fingers, then release it.

Discussion: The balloon moves rapidly through the air in an erratic pattern. Its motion is due to the force of the air leaving the nozzle of the balloon. This is explained by Isaac Newton's Third Law of Motion, two bodies are involved in every force found in nature, the body that exerts the force and the body that receives the force. Forces exist in pairs and never alone. For every force in one direction there is an equal and opposite force exerted in the opposite direction. In the case of the air-filled balloon the air escaping from the balloon was the body that exerted the force and the balloon received the force. The

escaping air thus provided the action force which resulted in the reaction force of the balloon in the opposite direction. The hot gases escaping through the nozzles of a rocket engine have the same effect on the rocket body as the air did on the balloon.

2. Action and Reaction in a Guided Missile (Demonstration and Activity K-6)

Materials: Balloon, sheet of $8\frac{1}{2}$ by 11 inch construction paper, two paper clips, and a ball of string.

Procedure: Construct a 4 inch cylindrical rocket from construction paper as illustrated in Figure 13.1. Tie one end of a length of string to the back of a chair and have a student hold the other end in his hand. Insert a long narrow balloon into the rocket body and inflate it. With your finger squeeze the nozzle of the balloon together and hook the rocket onto the string, using two paper clips as shown. Release the nozzle to allow the air to escape. What happens to the rocket?

Discussion: Isaac Newton's Third Law of Motion, *action-reaction*, again prevails. See results of Activity 1 for explanation.

3. Action and Reaction on Roller Skates (Demonstration and Activity 4-6)

Materials: Two pupils on roller skates, sand bag weight (5 lbs.).

Procedure: Have the pupils on roller skates stand or squat facing each other one foot apart. Have one student try to push the other student away from him with his hands, without causing himself to move in the opposite direction. Now have the children play catch with the sand bag. Have one child heave the sand bag backward between his legs. Be sure that each student keeps his roller skates parallel.

Discussion: The child doing the pushing will move in the opposite direction of the child being pushed. As the children play catch with the sand bag, they will also move in opposite directions and become separated. As the student heaves the sand bag backward between his legs, he will move forward in the opposite direction from that of the sand bag. This is another example of Newton's Third Law of Motion, *action-reaction* as explained in Activity 1 in this section.

PAPER CLIPS

Figure 13.1

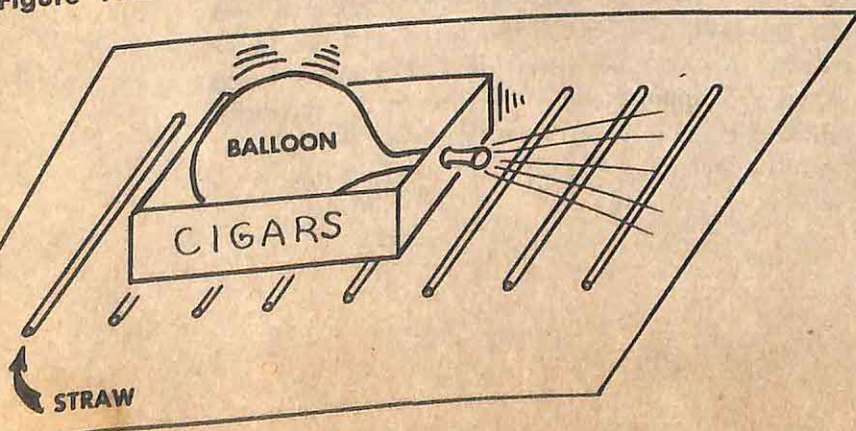
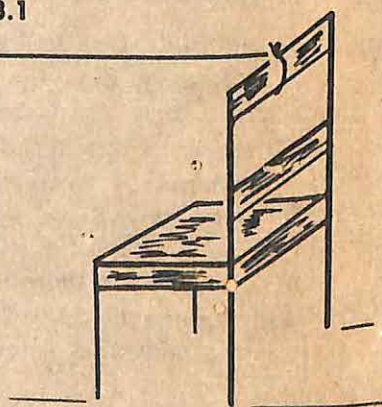
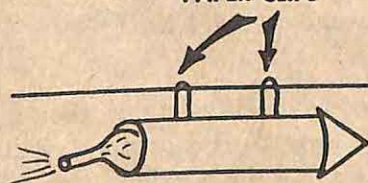
BALLOON

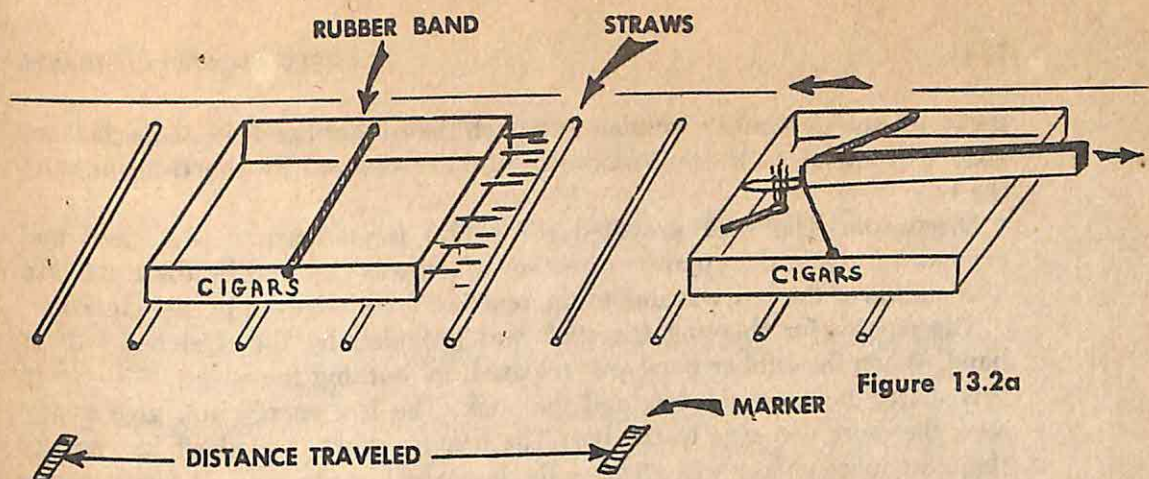
Figure 13.2

BALLOON

CIGARS

STRAW





4. Action and Reaction of a Swinging Baseball Bat (Demonstration and Activity 4-6)

Materials: One swivel chair or piano stool, baseball bat.

Procedure: Stand on the swivel chair or piano stool with the bat in hand. Attempt to swing the bat as if to hit a baseball. What happens?

Discussion: As the bat is swung forward, the feet and legs move in the opposite direction. This is made possible by the rotation of the swivel chair. Another example of action and reaction.

5. Action and Reaction of a Shoe Box Rocket (Demonstration and Activity K-6)

Materials: Shoe box, a balloon and a dozen straws.

Procedure: Cut a hole at one end of a shoe box large enough to hold the neck of a balloon, as illustrated in Figure 13.2. Inflate the balloon and pinch its neck together with your fingers to prevent the air from escaping. Place the box on several straws, which will act as rollers, as shown in Figure 13.2. Release the neck of the balloon. What happens?

Discussion: The box will move rapidly over the straws in the opposite direction of the air escaping from the balloon.

6. Experimenting with the Weight of Burning Rocket Fuel (Demonstration and Activity 4-6)

Materials: Cigar box, rubber band, box of soda straws, string, matches, and four wooden sticks of varying weights. (See Figure 13.2a.)

Procedure: Stretch a rubber band across the middle of a cigar box, using thumb tacks to hold it in place. Tie a string a few inches long to the middle of the rubber band. Pull on the string to form a "sling shot" with the rubber band, and anchor the string to the narrow end of the box with a thumb tack.

Place the box on several straws, which will act as rollers, as shown. Lay out a number of straws several feet ahead of the cigar box. Place a marker on the table or floor next to the front edge of the box. Now load the lightest of the sticks into the rubber band sling shot. To "fire" the sling shot, burn the string with a burning match. Follow this procedure in firing the remaining 3

sticks, paying particular attention to stretch the rubber band the same distance each time. After each firing mark the distance covered by the front edge of the box.

Discussion: The stick provided the action force when it was fired and exerted a force in the opposite direction which was received by the cigar box. The motion of the box was due to the reaction force received by the cigar box.

The energy for shooting the stick was provided by the stretched rubber band. When the rubber band was released, by burning the string, this energy was shared between the box and the stick. The less energy you give to the stick the more you give to the box. The heavier sticks carried off less energy therefore more energy was given to the box which made it travel faster, hence farther.

The problem of finding a rocket fuel which can produce the most energy with the least weight is of great importance to rocket scientists.

7. A CO₂ Rocket (Demonstration and Activity 2-6)

Materials: A CO₂ cartridge with firing mechanism, a rocket shaped vehicle made of balsa wood, string, and hooks.

Procedure: String up a string between two points 50 feet apart. Place the CO₂ cartridge in the hole provided for it in the back end of the balsa wood rocket. Hang the rocket on the string by two eye hooks as illustrated in Figure 13.3. Puncture the CO₂ cartridge with the firing mechanism.

Discussion: Immediately following the firing of the CO₂ cartridge the toy rocket moves quite rapidly along the string. As the compressed gas is released it creates an *action* force to which the resulting *reaction* force is the flight of the rocket.

8. Action and Reaction with a Steam Propelled Boat (Demonstration and Activity 2-6)

Materials: Small empty lighter fluid or oil can, wire coat hanger, small jar lid, alcohol, water, and a large basin or aquarium, and cake tin. (Figure 13.3a.)

Procedure: To construct a "steam-jet boat," bend a wire coat hanger into a stand to hold the lighter fluid can. Rinse out the inside of the lighter fluid can with water several times to be sure there is no lighter fluid in it. Lighter fluid is inflammable and its fumes are explosive. Pour about one fluid ounce of water into the can after rinsing. Pour some alcohol in a jar lid and place it in the center of a cake tin. Place the lighter fluid can and wire bracket in the cake tin. Float the cake tin in a basin of water. Ignite the alcohol and observe what happens as the water in the lighter fluid can is heated.

Discussion: The burning alcohol will heat the water in the can and turn it into a gas—steam. As the water turns into steam it expands and is forced through the small opening of the can, which acts like a nozzle of a rocket engine. The boat begins to move slowly as the *action* force due to the steam

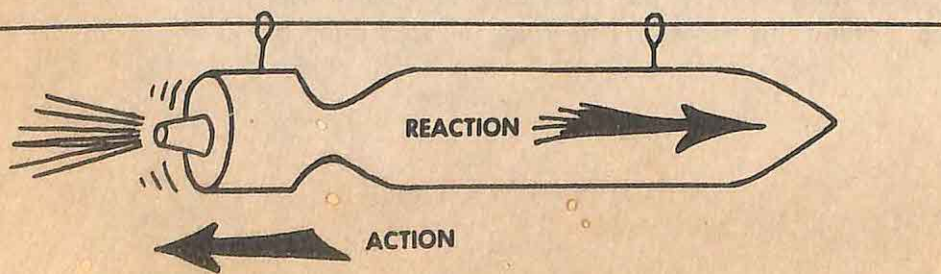


Figure 13.3

escaping through the nozzle creates a *reaction* and transmits this force to the cake tin. Hence we have a steam-jet driven boat.

9. Isaac Newton's Second Law of Motion: Acceleration (Demonstration and Activity 4-6)

Materials: A ball

Procedure: Throw the ball straight up into the air. After it returns, throw it up with a greater speed.

Discussion: The ball will fall back to earth because of the pull of gravity. The gravitational pull of the earth slows the ball's upward movement. The faster the ball goes at the start, the farther it can travel upward as gravity is acting upon it slowing it down and causes it to fall back to earth.

10. Increasing Speed by Staging (Demonstration and Activity 4-6)

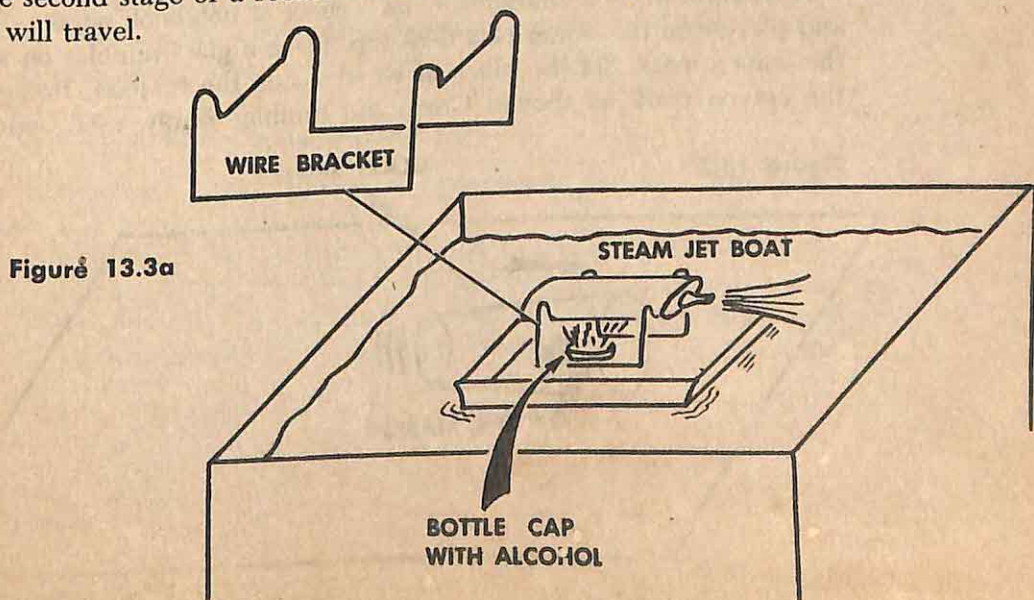
Materials: Tennis ball, 100 foot tape measure and a toy wagon.

Procedure: Take a group of children outdoors in the school ground. Mark a line on the ground or cement walk. Have a student sit in the wagon with a tennis ball in his hand. Bring the front wheels of the wagon up to the mark on the ground with the student sitting in the wagon facing forward. Have the student throw the ball as far as he can from the sitting position. Measure the distance the ball was thrown from the mark on the ground to the spot where it first struck the ground in its trajectory.

Return the ball to the student in the wagon and move the wagon about 25 feet from the line and perpendicular to it. Have another student pull the wagon toward the mark on the ground moving as fast as he can. When the front wheels of the wagon touch the line, signal the student to throw the ball as hard as he can. Repeat this action 3 times.

Measure the distance the ball travels each time it is thrown. Compare the distance the ball travels when thrown from a stationary wagon and from a moving wagon.

Discussion: The ball in most cases will travel farther when thrown from a moving vehicle. The ball already has a running start in the moving wagon. Throwing the ball after a running start is like firing the second stage of a rocket. The second stage of a rocket further increases the speed and distance the rocket will travel.



11. Increasing Speed by Staging, Using a Toy Rocket (Demonstration and Activity 2-6)

Materials: Two stage water-filled toy rocket.

Procedure: Procure a two stage plastic toy rocket from a hobby shop or toy shop. There are several good models which make excellent devices for investigating the principles of staging.

These toy rockets are water filled and the pressure necessary for acceleration is provided by air pressure which is forced into the body of the rocket with an air pump.

Have the students fire the rocket, outside in a grass field, using only one stage and observe the height to which it travels. Recover the rocket and fire it again using both stages. Is there any difference in the height the rocket travels using two stages?

Discussion: The rocket will travel higher when both stages are used.

B. PLACING A SATELLITE IN ORBIT

1. Isaac Newton's First Law of Motion: Inertia, Body at Rest (Demonstration and Activity 4-6)

Materials: Glass tumbler or tin can, and a sheet of notebook paper.

Procedure: Set a glass tumbler or tin can on a sheet of notebook paper in the center of a table top. Hold one end of the paper tightly in your hand and pull the paper out from under the object with a quick jerk. What happens to the object?

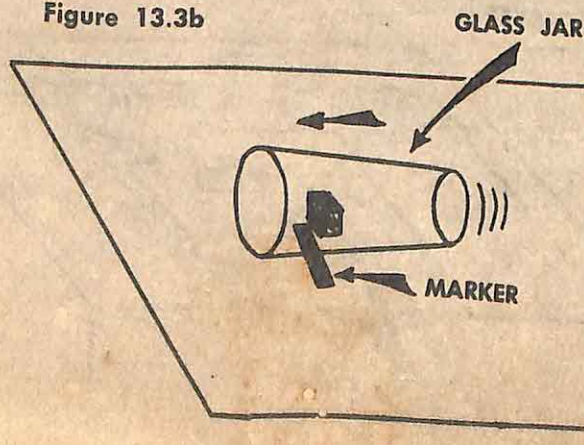
Discussion: The tumbler or tin can tends to remain in place on the table as the paper moves out from under it. This is part of Isaac Newton's first law of motion, which states that a body at rest tends to stay at rest.

2. Inertia: Body at Rest (Demonstration and Activity 4-6)

Materials: Glass tumbler, small block of wood, sheet of notebook paper, and a crayon. (See Figure 13.3b.)

Procedure: Mark a straight line on a sheet of notebook paper with a crayon and place it in the center of a desk top. Place a glass tumbler on its side over the crayon mark. Set the block of wood inside the tumbler, lining it up with the crayon mark as shown. Grasp the tumbler firmly with your hand and

Figure 13.3b



move it forward *quickly* for a distance of 2 or 3 inches and stop quickly. What happens to the block of wood and its position inside the tumbler in relation to the crayon mark? The secret to the success of this demonstration lies in the speed at which you move the tumbler.

Discussion: The block of wood tends to stay at rest while the tumbler moves under it. This is made evident by the position of the block of wood over the crayon mark. This demonstrates the *inertia* of a body at rest.

3. Inertia of a Body at Rest (Demonstration and Activity 4-6)

Materials: Toy doll, toy wagon, two sticks, and a cardboard box.

Procedure: Construct a seat from a cardboard box and place it in a toy wagon, as illustrated in Figure 13.4. Support the seat on two transverse sticks as shown, and place the doll in a sitting position in the seat. To give this demonstration some character give the doll a name like "Ida Inertia," or some comparable name, as you refer to the sequence of events. Start the wagon moving forward with a sudden jerk. What happens to Ida Inertia?

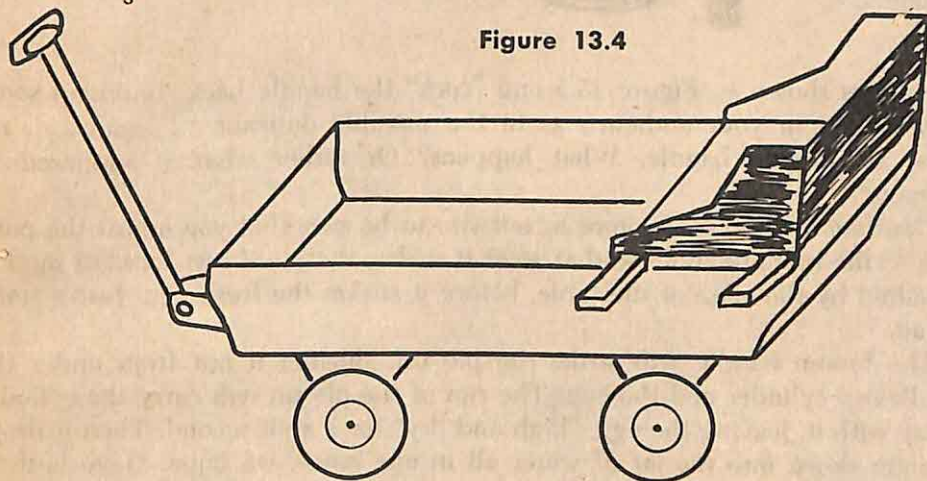


Figure 13.4

Discussion: Ida Inertia is an object at rest which tends to stay at rest—and does—as you suddenly move the wagon out from under her, causing her to fall to the floor. If necessary, repeat this demonstration several times to reinforce the concept of inertia of a body at rest.

4. Inertia of a Body at Rest (Demonstration 4-6)

Materials: Wide mouth jar, cardboard cylinder, pie tin, broom, hard boiled egg, fresh egg, desk or table, and water.

Procedure: Set up the equipment as illustrated in Figure 13.5. Center the egg, hard boiled or fresh, and cardboard cylinder over the center of a wide mouth jar $\frac{3}{4}$ -filled with water. Adjust the apparatus so that the pie tin extends about one inch beyond the edge of the table top. Step on the straw end of the

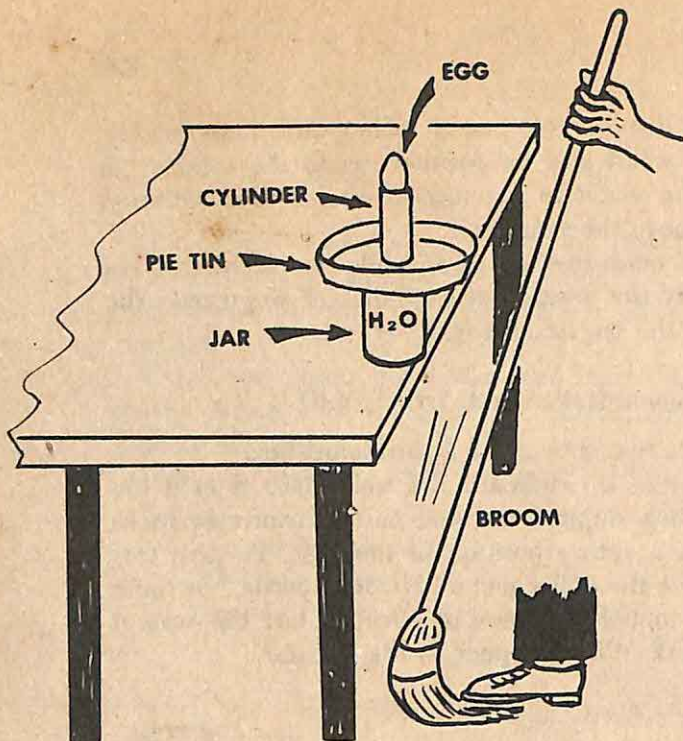


Figure 13.5

broom, as shown in Figure 13.5 and “cock” the handle back. Build up some anticipation in your audience as to the possible outcome . . . and . . . release the broom handle. What happens? Or rather what is supposed to happen?

Discussion: Oh, yes, I forgot to tell you to be sure that you adjust the position of the broom handle so that after it strikes the pie tin its forward motion is halted by the edge of the table, before it strikes the fresh egg. Just a small detail.

The broom handle will strike the pie tin, shoving it out from under the cardboard cylinder and the egg. The rim of the pie tin will carry the cylinder away with it, leaving the egg, “high and dry” for a split second. Then it drops straight down into the jar of water all in one piece, we hope. Have faith in Isaac Newton’s “first law of motion” and you will succeed. It is recommended that you practice with a hard boiled egg first. Good luck!

5. Inertia: Moving Body (Demonstration and Activity 4-6)

Materials: Glass tumbler and a small block of wood.

Procedure: Place a glass tumbler on its side on a table top, with a small block of wood inside near the open end. Slide the tumbler along the table top for a distance of at least one foot, then stop it suddenly. What happens to the block of wood?

Discussion: The block of wood is at rest and has a tendency to remain at rest until it is accelerated by the friction between it and the bottom of the glass tumbler. It becomes an object in motion. When the tumbler stops, the block of wood continues to move in a straight line.

This is the same motion experienced when a car you are riding in comes

to a sudden stop. Your body continues to move and will not stop until the dashboard or windshield stops you.

This is the other part of Isaac Newton's First Law of Motion, which states that a body in motion tends to stay in motion at the same speed unless it is restricted by an outside force.

6. Inertia: Moving Body (Demonstration and Activity 4-6)

Materials: Toy doll, toy wagon, and two sticks.

Procedure: Set up the equipment as illustrated in Figure 13.4 and described in Activity 3 of this section.

Accelerate the wagon slowly so as not to pull the wagon out from under the doll. Stop the wagon's forward motion abruptly. What happens to the doll?

Discussion: The doll is an object in motion which tends to continue in motion in the same direction in which it had been traveling. The resistance of the air, and the friction of the doll striking the floor slowed it down until it stopped. This is what happens to you when your car or school bus comes to a sudden stop: you keep moving and may only be stopped by the dashboard, the windshield, or the seat in front of you. Do you see why seat belts are important?

7. A Moving Object Tends to Travel in a Straight Line (Demonstration and Activity 4-6)

Materials: Tennis ball, string, and tape.

Procedure: Fasten one end of a 3 foot length of string to a tennis ball. Hold the other end of the string in your hand and twirl the ball in a vertical plane in front of you as illustrated in Figure 13.6. Release the end of the string. What happens to the ball?

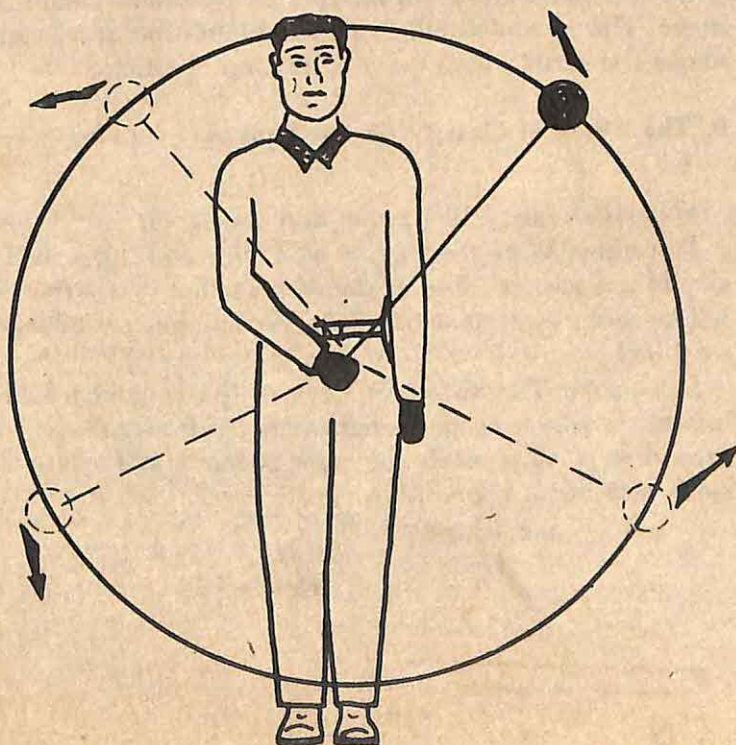


Figure 13.6

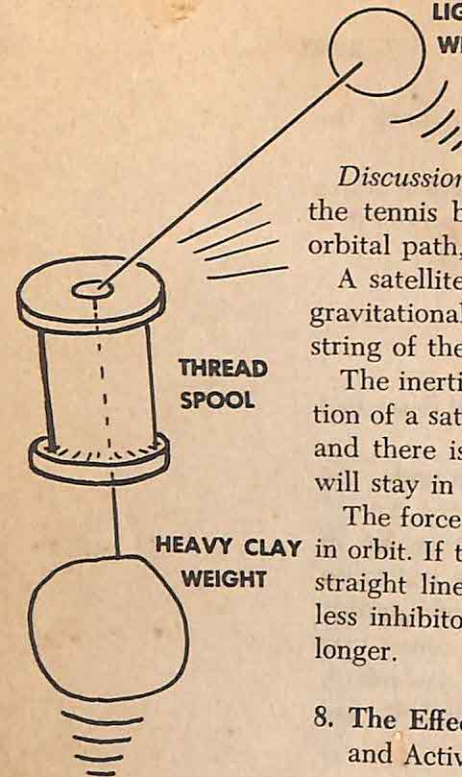


Figure 13.7

Discussion: When released, and before gravity has an appreciable effect, the tennis ball will fly off in a straight path in a direction tangent to the orbital path, as illustrated in Figure 13.9.

A satellite, however, stays in an orbital path around the earth because the gravitational pull of the earth bends its straight line path. The tension in the string of the ball is analogous to the force of gravity.

The inertia of a moving body is one of the principles which governs the motion of a satellite in orbit. If the speed and altitude of a satellite are just right and there is no outside force other than gravity acting upon it, the satellite will stay in orbit forever.

The force of gravity of the earth bends the path of the satellite and keeps it in orbit. If the force of gravity was not present the satellite would go off in a straight line. (*Newton's First Law*) The higher the orbit of a satellite, the less inhibitory air resistance it will encounter and hence it will stay in orbit longer.

8. The Effect of Gravity on the Path of a Moving Satellite (Demonstration and Activity 4-6)

Materials: A tennis ball and table.

Procedure: Roll the ball off the edge of the table and mark the spot where it hits the floor. Do this several times, increasing the speed each time.

Discussion: Gravity pulls on the ball each time, causing it to fall toward earth in an arc bending toward the earth. With an increase in speed the ball moves farther horizontally while falling. For the ball to continue in an orbit around the earth without hitting the ground, it would have to travel at a speed of about 5 miles per second, or about 18,000 MPH. This would be impossible close to the earth because air resistance would cause the ball to slow down. This is why satellites are fired into orbit at a height of about 300 miles above the earth where there is little air resistance.

9. The Effect of Gravity on the Path of a Moving Satellite (Demonstration 4-6)

Materials: Steel ball bearing and a magnet.

Procedure: Place the magnet on a table and roll a steel ball past it. The ball should not pass so close to the magnet that it is attracted to it, yet it should not be so far away that the magnetic field has no influence on the path of the steel ball.

Discussion: The attractive force of the magnetic field will cause the steel ball to deviate from its straight path. The magnet will attract the steel ball toward it in very much the same manner as the gravitational force of the earth acts upon a satellite.

BAR MAGNET

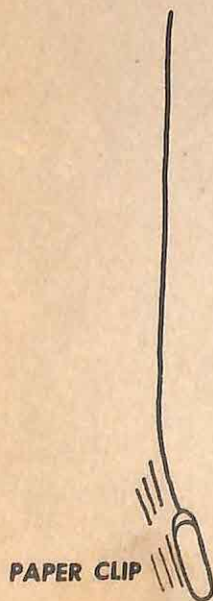
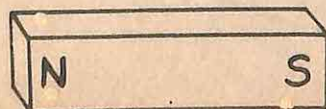


Figure 13.8

10. The Effect of the Speed of a Satellite on Its Orbit (Demonstration 4-6)

Materials: Thread spool, 3 foot length of thread, two clay balls 1 inch and $2\frac{1}{2}$ inches in diameter.

Procedure: Place the thread through the hole in the spool and secure the clay balls to each end of the thread, as illustrated in Figure 13.7. The small clay ball will represent the satellite in orbit. The tension on the string created by the larger clay ball will represent the force of gravity acting on the satellite. Swing the small clay ball in a circle by holding onto the spool with your fingers as shown. Hold the larger clay ball in your other hand until it can be held up by the centrifugal force of the swinging smaller clay ball.

Discussion: The centrifugal force exerted by the smaller swinging clay ball will hold up the weight of the larger clay ball.

If a satellite slows down it will be pulled toward the earth by the force of gravity. This can be demonstrated by slowing the circular motion of the smaller clay ball.

11. Overcoming Gravity to Escape into Outer Space (Demonstration 4-6)

Materials: Magnet, steel paper clip and string.

Procedure: Suspend a paper clip from the end of a length of string, as illustrated in Figure 13.8. Hold a magnet in one hand and the suspended paper clip in the other hand as shown. Keep moving the paper clip closer to the magnet until it is attracted to it. Find the distance from the magnet at which the paper clip is barely attracted to the magnet.

Discussion: The paper clip may be compared to a rocket which must escape the attractive force of the earth's gravity to "break away" into outer space. One way for a rocket to escape the earth's gravitational pull is to attain a top speed of 25,000 MPH close to the surface of the earth.

12. Placing a Satellite or Capsule into Orbit (Demonstration 4-6)

Materials: Flannel board, flannel-backed three-stage rocket cutouts, and speed labels.

Procedure: The flannel-backed cutouts needed for this demonstration are illustrated in Figure 13.9. These are comprised of a three stage rocket and the labels indicating speed to which each stage accelerates.

A satellite placed in orbit at an altitude of 300 miles must attain a speed of 18,000 MPH. To attain this speed more power is needed than can presently be provided by a single stage. This problem is solved by including several stages. The first stage is the largest and must produce the most power to overcome its own inertia and that of the other two stages, plus the force of gravity and the air resistance closest to the earth.

The first stage attains a speed of 4,000 MPH just as the fuel burns out. With a running start, now of 4,000 MPH, the second stage ignites as the first stage drops off, and accelerates to a speed of 10,000 MPH. With a running start of 10,000 MPH the third stage ignites as the second stage drops off. At

this time it attains a "horizontal" flight path, following the curvature of earth, and the satellite or capsule is shot forward into orbit around the earth.

Discussion: The flannel board cutouts can be manipulated as many times as necessary to reinforce the concepts mentioned above.

13. Shooting a Space Craft into Outer Space (Demonstration 4-6)

Materials: Flannel board, flannel-backed three-stage rocket cutouts, and speed labels.

Procedure: Refer to demonstration 12 and Figure 13.9 for a description of the flannel-backed 3 stage rocket necessary for this demonstration. The speed label for the third stage of rocket will be 25,000 MPH instead of 18,000 MPH.

Discussion: For a rocket to escape the influence of the earth's gravity it must accelerate to a speed of 25,000 MPH which is known as the *escape velocity*. This is accomplished by rocket staging.

The speed required for the rocket to continue climbing as it gets further out into space need not continue to be 25,000 MPH because the pull of the earth's gravity decreases as the rocket gets further away from the earth.

When a rocket is fired toward the moon its third stage must accelerate to a speed of 25,000 MPH for it to escape the earth's force of gravity. After the fuel in the third stage burns up, the rocket keeps moving due to inertia, but will slow down as it continues to travel toward the moon. At a distance of about 210,000 miles from the earth and about 30,000 miles from the surface of the moon, the moon's gravitational pull becomes the dominating attractive force on the rocket.

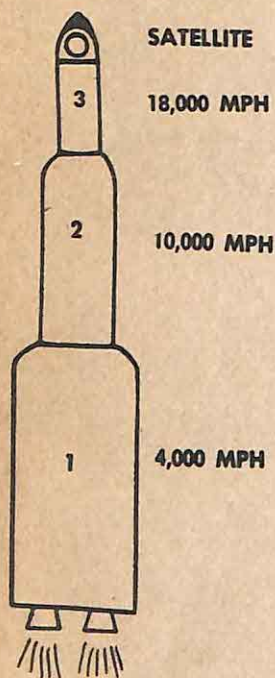


Figure 13.9

C. MAN IN SPACE

1. Constructing a Space Capsule (Activity K-6)

Materials: Large cardboard box (the size used for shipping refrigerators, TV sets or large pieces of furniture), saw, waste paper basket, and a large sheet of construction paper.

Procedure: Have the children cut a door and windows in the box as illustrated in Figure 13.10. Cover the windows with sheets of cellophane or clear acetate. To streamline the capsule, invert a waste paper can over the top of the box and add a nose cone made from a sheet of construction paper as shown.

Discussion: This mock-up of a space capsule will provide a basis for further study into the needs of an astronaut in space flight.

2. Making and Mounting a Periscope in a Capsule (Activity 2-6)

Materials: Milk carton, two pocket mirrors, and a sheet of cardboard.

Procedure: Refer to Chapter VIII, Section B, Activity 2, for direction in constructing a periscope.

Refer to Figure 13.11 for directions for mounting the periscope in the space

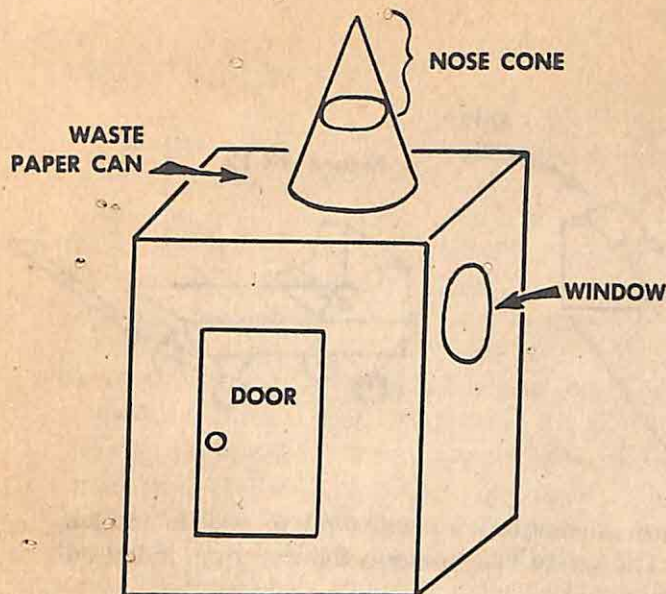


Figure 13.10

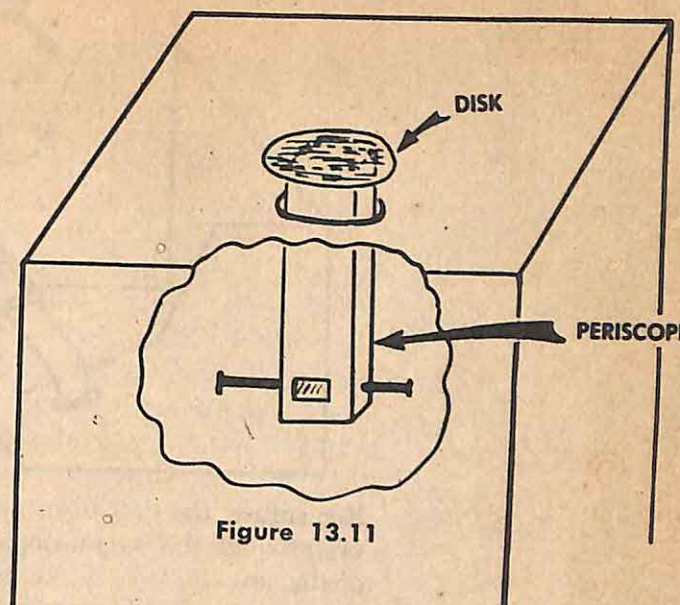


Figure 13.11

capsule. Cut a hole in the top of the capsule as shown. Glue a cardboard disk, with a greater diameter than the hole, on top of the periscope to prevent it from falling into the capsule.

Discussion: To see outside the capsule, raise the periscope and turn it left and right. When not in use retract it. The periscope in a real capsule is retractable. This protects it from the intense heat of re-entry into the earth's atmosphere and adds to the streamlined design of the capsule.

3. Using Electricity in a Space Capsule (Activity 2-6)

Materials: Refer to Chapter VI for materials needed for constructing electrical circuits.

Procedure: Install several electrical circuits in the space capsule; cabin lights, signal lights, and buzzer circuits.

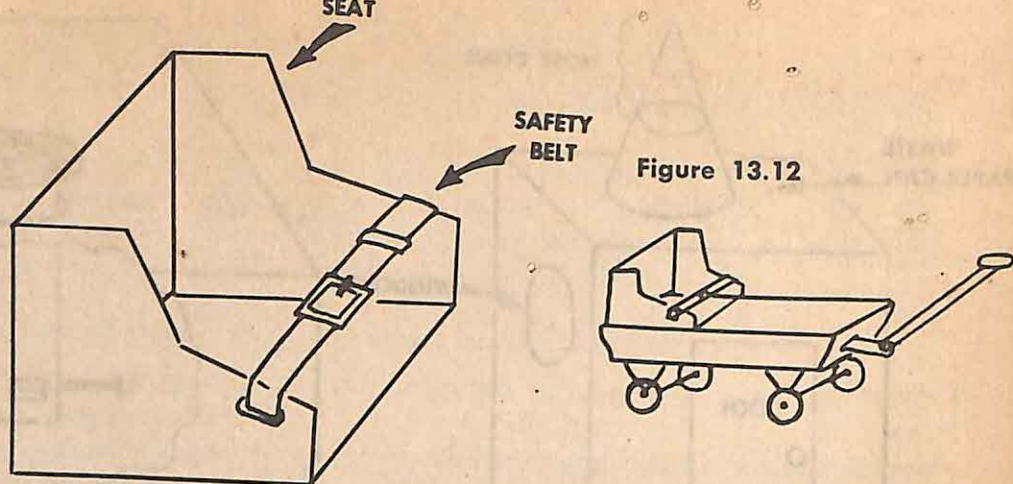
Discussion: This activity provides an excellent opportunity for the children to apply their knowledge of electrical circuits and put them to practical use.

4. Safety Belts in a Capsule (Demonstration and Activity 2-6)

Materials: Doll, toy wagon, small cardboard box, a belt or heavy cord, and tape.

Procedure: Cut a cardboard box into the form of a chair, as illustrated in Figure 13.12. Cut slits on each side of the chair to hold a safety belt. Fasten the chair in the wagon with tape. Place the doll in the chair without the safety belt, and start the wagon forward with a sudden jerk. What happens to the doll? Stop the forward motion abruptly. What happens to the doll? Fasten the safety belt around the doll and again follow the procedure described above. What happens to the doll?

Discussion: When the wagon is started with a sudden jerk the doll is forced back into the seat. This same action takes place when your car starts forward quickly. The doll flies out of the seat when the wagon is stopped abruptly.



Remember, the doll is an object in motion and will tend to stay in motion, even though the wagon stops. The safety belt prevents the doll from flying out of the seat.

A man in a space capsule needs a safety belt too, for much the same reason. When a space capsule is shot into the air by a rocket, it reaches very high speeds in just a short time. The rocket and the capsule might spin before entering orbit, which would throw the space pilot out of his seat.

Have the children construct a seat for their capsule, and include a safety belt.

5. Making a Parachute (Activity K-6)

Materials: A 2 by 2 foot square cotton cloth, four 2 foot lengths of string, and modeling clay.

Procedure: Cut a piece of cotton cloth (an old sheet will do) into a 2 foot square. Tie one end of a 2 foot length of string to each corner, as illustrated in Figure 13.13. Tie the loose ends of the strings together, making sure that they are all the same length. Shape a piece of modeling clay weighing 2 or 3 ounces into the form of a space capsule. Attach the parachute *shrouds* (4 strings) to the capsule as shown in Figure 13.13. To test your parachute drop it from a high place, like the top of a ladder or from a second story window of your school. Why does a parachute fall slowly to earth?

Discussion: The parachute will fill with air and gently float to earth. The air molecules pile up under the parachute and resist its downward motion. Remember: air is something.

6. Collecting Survival Equipment for a Space Capsule (Activity K-6)

Materials: Inner tube from a tire, two balloons, string, toy gun, homemade flashlight, mirror, pocket knife, fish hooks, shoe box, container of water, glass jar, radio and jack knife.

Procedure: Have the children investigate what survival equipment is necessary in a space capsule by reading reference books, magazines, and newspaper articles which contain information, stories, and articles on past and planned future flights into space. Have the children collect these materials and include them in their space capsule.

Discussion: Much of the real equipment would be impossible to obtain, although substitute materials and equipment can be found. An inner tube can be used as a life raft. A life preserver can be constructed from two balloons joined together with string. A flashlight can be made from a dry cell, a bulb, and wire, as suggested in Chapter VI. A mock radio can be made from a cardboard box. A shoe box can be used to store food. A pocket mirror can be used as a daylight signaling device, and a toy gun as a sound signal device. Fish line and hooks are easy to obtain, as are glass jars for water and a make-believe oxygen tank. Jack knives are plentiful among the Scouts in the classroom.

Proper storage of the survival gear poses another problem which the children will have to solve. Remember, equipment in a space capsule must be tied down or it will float around during periods of zero gravitation (weightlessness). The equipment mentioned in this activity includes only a few suggestions. The children in your classroom will undoubtedly think of others.

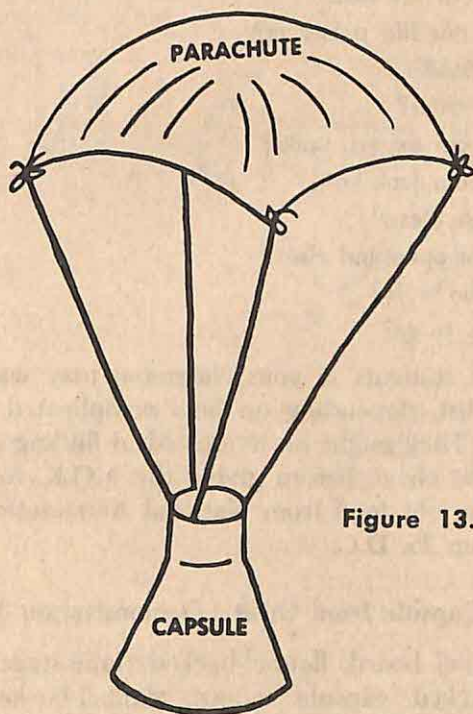


Figure 13.13

7. A Check-Off List for Space Flight (Activity K-6)

Materials: Check list for space pilots.

Procedure: No space flight would be successful if the space pilot did not carefully check all of his equipment to make sure it is operating properly. He cannot depend on his memory to check all the items which are essential for a successful flight. To aid him in accomplishing this task, he uses *check-off* lists which list all the items he must check. The following check list is suggested for use by your space pilot to use in his space capsule.

CHECK LIST FOR SPACE PILOTS

	Yes	No
1. Does the periscope go up and down?	_____	_____
2. Does the periscope turn?	_____	_____
3. Is the parachute tied to the capsule?	_____	_____
4. Do we have a safety belt for the chair?	_____	_____
5. Does the signal light work?	_____	_____
6. Does the cabin light work?	_____	_____
7. Does the emergency flash light work?	_____	_____
8. Do we have a pocket mirror?	_____	_____
9. Do we have a fish line and hook?	_____	_____
10. Do we have a signal gun?	_____	_____
11. Do we have our life raft?	_____	_____
12. Do we have our life preserver?	_____	_____
13. Do we have food?	_____	_____
14. Do we have water?	_____	_____
15. Do we have our oxygen tanks?	_____	_____
16. Do we have our jack knife?	_____	_____
17. Is the window clean?	_____	_____
18. Does the door open and close?	_____	_____
19. Does the radio work?	_____	_____
20. Are we ready to go?	_____	_____

Discussion: The students in your classroom may want to add more items to this check-off list, depending on how complicated a space capsule they have constructed. They might be interested in finding out how many items a real astronaut must check before giving the A.O.K. for launch. Most of this information can be obtained from National Aeronautics and Space Administration, Washington 25, D.C.

8. Recovering a Capsule from Orbit (Demonstration 3-6)

Materials: Flannel board, flannel-backed three-stage rocket cutouts, speed labels, flannel-backed capsule cutout, flannel-backed parachute, flannel-backed retro-rocket firing pack cutout.

Procedure: The procedure for firing a capsule into space is illustrated in Demonstration 12 of section B of this chapter.

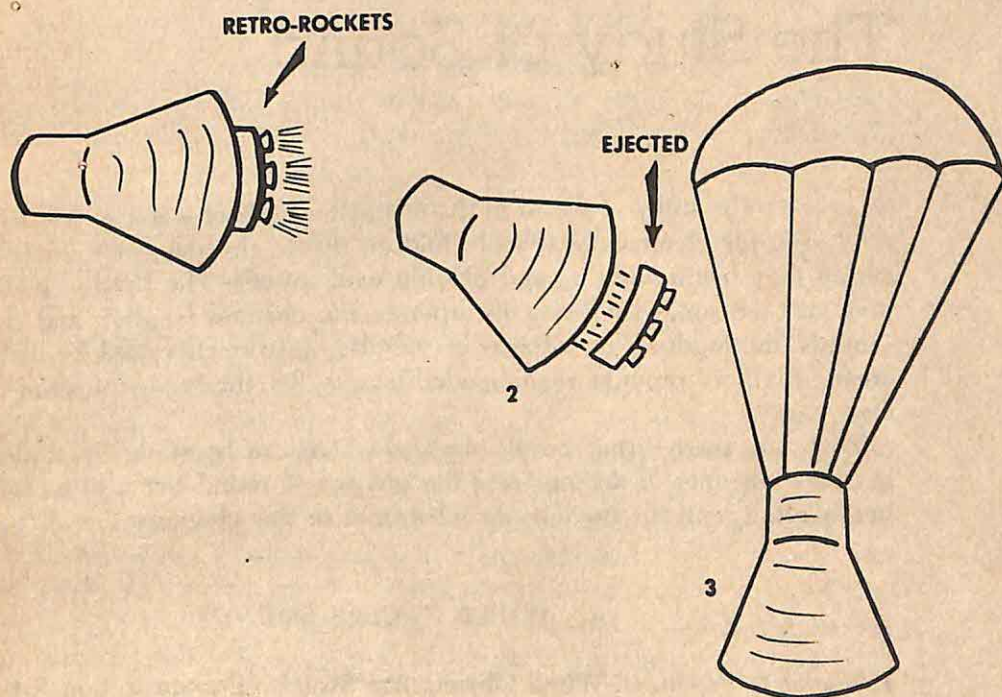
Using the flannel-backed capsule cutouts with retro-pack and parachute, the procedure for recovering a space capsule is as follows.

The capsule is in orbit traveling at a speed of almost 18,000 MPH. Before it can return to earth, it must be slowed down. This is accomplished by directing the capsule's retro-firing rocket in the direction of the capsule's flight, as illustrated in Figure 13.14, and firing the retro-rockets. As the capsule slows down, the force necessary to hold it in orbit decreases and the force of gravity

pulls it toward the earth's surface. The retro-pack is then jettisoned and the entire heat shield is exposed as the capsule plummets to earth. At 10,000 feet altitude above the earth, the parachute opens and the capsule floats earthward.

Discussion: There are many other interesting events, not mentioned here, which occur during the re-entry flight. The children can explore these details in books and magazine articles. They might want to learn what the heat shield is made of and how it operates. They may want to know at what angle the capsule must enter the earth's atmosphere in order to prevent the capsule from burning up due to the friction of the air. There are many other such details which could be investigated.

Figure 13.14



XIV



The Study of Sound

The study of sound in the elementary school is not a new adventure for elementary school children. From the day they enter kindergarten they begin working and playing with sounds. The rhythm games they play and the songs they sing incorporate the changes in pitch and dynamics (that is, the loudness or softness of sounds). Instruments used by children to create rhythms provide ready-made devices for the study of sound in the classroom.

There are many other simple devices which can be made by students and teachers not only to demonstrate the physics of sound but also to use in experimenting with the medium as illustrated in this chapter.

A. WHAT CAUSES SOUND?

1. Sound Is Produced When Objects Are Struck (Demonstration K-6)

Materials: Hammer, tin can, book, and a tuning fork.

Procedure: Strike a tin can with a hammer. Drop a book on a desk top. Strike a tuning fork with your hand. What happens?

Discussion: Sound is produced when the hammer strikes the can, when the book is dropped on the desk, and when the tuning fork is struck. Why? The next few demonstrations will help you to understand this phenomenon better.

2. Vibrations Produce Sound (Demonstration and Activity K-6)

Materials: 12-inch ruler.

Procedure: Extend a 12-inch ruler over the end of the edge of a table top or desk as illustrated in Figure 14.1. Hold one end down on the desk top and stroke the other end. What do you observe?

Discussion: The ruler vibrates and produces a sound. Shorten and lengthen the extended end of the ruler by moving it back and forth in relation to the edge of the table top as you stroke it. Do you notice any change in the sound it produces?

3. Vibrations Produce Sounds (Demonstration and Activity K-6)

Materials: Tuning fork and a pan of water.

Procedure: Strike a tuning fork with your hand and dip the vibrating prongs into a pan of water. What do you observe?

Discussion: When the tuning fork is struck, it produces a sound—a musical sound. When the prongs are dipped in the pan of water, they cause a splash because the rapidly vibrating prongs produce a disturbance in the water.

4. Vibrations Produce Sounds (Demonstration and Activity K-6)

Materials: Tin can, wooden mallet, and shallow pan of water.

Procedure: Place a tin can in the center of a shallow pan of water, open end down. Strike the top of the tin can gently with a wooden mallet or stick and observe the water surrounding the can.

Discussion: As the tin can is struck by the mallet, it vibrates, causing a sound and producing tiny waves radiating in all directions in the water around the can. This indicates that the can is vibrating.

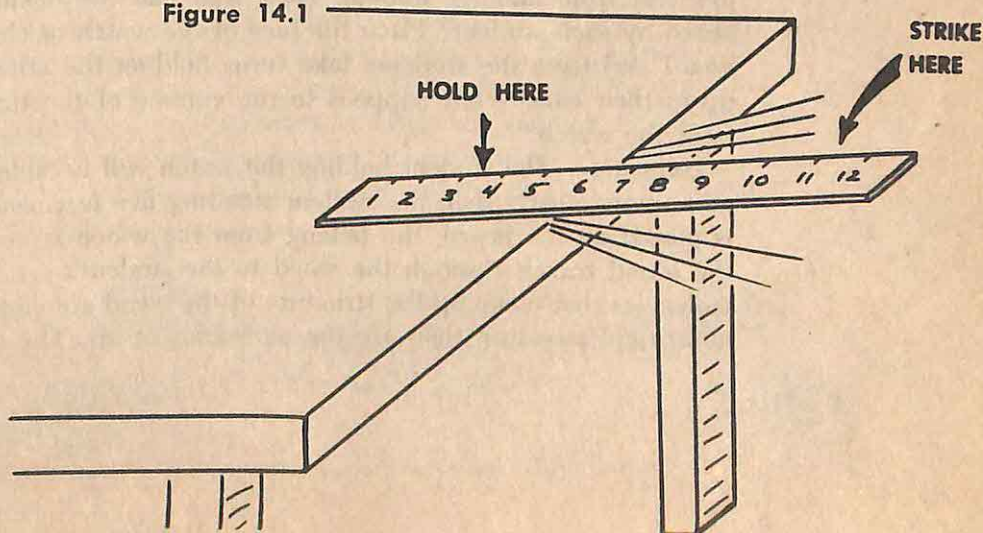
5. Vibrations Produce Sound (Demonstration and Activity K-6)

Materials: Ping pong ball, string, tape, and a tuning fork.

Procedure: Suspend a ping pong ball from one end of a two foot length of string, attaching the string to the ping pong ball with tape. Hold the other end of the string in one hand, suspending the ball. Grasp a tuning fork in your other hand, strike it against the rubber heel of a shoe to make it vibrate, and touch one prong to the ping pong ball. What happens?

Discussion: When the tuning fork is struck it produces a sound, which is due to the vibration of the tuning fork. These vibrations are made evident as the fork prong touches the ping pong ball and causes it to be repelled as it is tapped by the vibrating fork prong.

Figure 14.1



6. Vibrations Produce Sound (Demonstration and Activity K-6)

Materials: Tin can and tuning fork.

Procedure: Strike a tuning fork with your hand and touch a tin can with one of the prongs. What happens?

Discussion: As the tuning fork is struck, it will produce a sound. This sound is caused by the fact that the tuning fork is vibrating. The vibrations of the tuning fork are made evident by the fact that the tuning fork bounces away from the tin can or causes the tin can to move away from it. It also causes the tin can to vibrate and produce a sound.

7. Vibrations Produce Sound (Demonstration and Activity K-6)

Materials: Hair comb.

Procedure: Run your finger up and down the row of teeth on a hair comb. What causes the sound you hear?

Discussion: As your finger runs over the teeth of the comb, it causes them to vibrate. These vibrations produce the sound you hear.

B. HOW SOUNDS TRAVEL

1. Sound Travels in Waves (Demonstration and Activity K-6)

Materials: Large, round, shallow pan; water; and some small pebbles.

Procedure: Fill a pan with water and drop several pebbles into the water one by one. What happens?

Discussion: As the pebbles strike the water, they produce small waves on the surface of the water. These waves are very much like the sound waves which travel through the air to our ears.

2. Sound Can Travel Through Solid Materials (Demonstration and Activity K-6)

Materials: Wrist watch or small clock and narrow board about 5 feet long.

Procedure: Have a student hold a wrist watch in his hand at a distance of five feet from another student. How well can the ticking of the watch be heard by each student? Place the face of the watch or clock on one end of a board and have the students take turns holding the other end of the board up to their ears. What happens to the volume of the ticking sound emitted from the watch?

Discussion: The student holding the watch will be able to hear the ticking noise more clearly than the student standing five feet away. When the watch is placed on the board, the ticking from the watch is heard much louder as the sound travels through the wood to the student's ear. This is because the molecules that make up the structure of the wood are closer together and in a more rigid structure than are the molecules of air. The closer the molecules

are in the transmitting medium, the less sound energy is lost in transmission, which accounts for less loss in volume. The sound energy will also travel faster in the more dense medium of a solid.

3. Sound Can Travel Through Liquids (Demonstration and Activity K-6)

Materials: Aquarium filled with water and two metal spoons.

Procedure: Hold a metal spoon in each hand; strike the spoons together. Can you hear the sound produced by the spoons? Submerge the spoons in an aquarium and strike them together again. Have a student place his ear next to and touching the side of the aquarium. Can the sound of the spoons be heard through the water?

Discussion: The sound of the spoons striking each other can easily be heard through the air. The sound produced by the spoons can also be heard loudly and clearly through the water. Sound can travel through liquids as well as through solids and gases. As in solids, the molecules in a liquid are very close together but not held in a rigid form; this accounts for the fact that sound travels faster in water than in air. The closer the molecules are in the transmitting medium, the less sound is lost in transmission, which accounts for less loss in volume. Sound energy will travel faster in the more dense medium of a liquid.

4. Sound Travels in Waves (Demonstration 3-6)

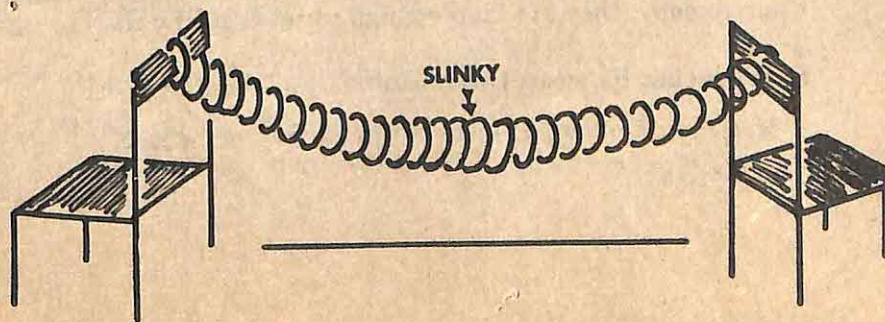
Materials: A toy "Slinky" and two chairs.

Procedure: Stretch a "Slinky" between two chairs placed at a distance of about eight feet apart as illustrated in Figure 14.2. After the "Slinky" has become completely motionless, gently compress two or three of the coils together at one end and then release them quickly. Watch the "Slinky" carefully. What happens to it?

Discussion: The "Slinky" appears to ripple first in one direction and then back again in the other direction. The rippling of the "Slinky" gets weaker as it travels back and forth. The rippling of the "Slinky" is analogous to the way sound travels through the air. The ripple was caused by the successive compression of each coil against the next coil.

Sound in the air is caused when a vibrating object forces the air molecules around it together suddenly. These molecules in turn press against the molecules in immediate proximity to them (like the coils of the "Slinky"). They in turn press against the molecules around them and so on. It is important to note here that none of the coils of the "Slinky" must move very far in order to compress its neighboring coil. The molecules in the air likewise do not have to travel very far in order to push against their neighboring molecules. In this manner sound waves in air travel outward from the source in a series of energy spheres.

Figure 14.2



5. The Character of Sound Waves (Demonstration 3-6)

Materials: Round balloon.

Procedure: Blow up a round balloon slowly and observe what happens to the rubber of the balloon as it gets larger and larger.

Discussion: As the balloon is blown up bigger and bigger, the rubber gets thinner and thinner, and the walls of the balloon become more transparent.

Sound waves are analogous to the rubber walls of the balloon. Sound waves are made up of energy walls which decrease in intensity at greater distances from the source.

6. Directing Sound Waves with a Megaphone (Demonstration and Activity K-6)

Materials: Large sheet of construction paper and a paper clip.

Procedure: Roll a sheet of construction paper into a cone which is open at both ends so that it looks like a megaphone. Hold the narrow end of the megaphone up to your lips and face the students. Continue to speak in a normal tone of voice, first as you face them and then as you slowly turn from side to side. Have the children listen carefully to the volume level of your voice as you turn away from them.

Discussion: The volume level of your voice will seem to decrease as the megaphone is turned away from the group. The megaphone confines the sound waves and keeps them from spreading out. Consequently, the sound waves in a path directly in front of the megaphone are louder than they would normally be if they were not confined. For this reason sound waves can be directed in a narrow channel, and unless you are in a path directly in front of the megaphone it becomes difficult to hear the sound.

7. Sound Waves Can Be Amplified When Confined in a Narrow Channel (Demonstration and Activity K-6)

Materials: A 6 foot length of cardboard tubing, metal tubing or pipe, and a wrist watch.

Procedure: Have a student holding a wrist watch in his hand stand about six feet from another student. How well can the second student hear the ticking of the watch at that distance? How well can the student hear the ticking of the watch if it is placed inside one end of a 6 foot length of tubing, and he holds the other end to his ear?

Discussion: The sound waves produced by the ticking of the watch are difficult or perhaps impossible to hear at a distance of six feet. When the watch is placed inside the tubing, the sound waves are confined to a very narrow channel and are prevented from spreading out and becoming less intense. Consequently, they are loud enough to be heard by the human ear.

8. Producing Echoes (Demonstration and Activity K-6)

Materials: Gallon jar, metal waste basket, or bucket.

Procedure: Hold your head a few inches from the opening of a gallon jar, waste can, or bucket and speak softly into it. What do you hear?

Discussion: An echo is heard as the sound waves bounce around from wall to wall inside the cavity producing an echo effect. An echo is really reflecting sound waves. Demonstration 4, section "A" of this chapter will help you to see how sound waves can bounce back and forth to create an echo. The rippling of the toy "Slinky" demonstrates this.

9. Sound Waves Can Be Absorbed (Demonstration and Activity K-6)

Materials: Door bell, $1\frac{1}{2}$ volt dry cell, wire, cardboard box, and some cotton cloth.

Procedure: Using a dry cell and wire, connect a bell in a simple circuit. Refer to Chapter VI for the construction of this simple circuit. Note the volume of the ringing bell. Place the bell inside a cardboard box, cover it with the lid, and again note the volume of the bell. Open the box and line the inside with cotton cloth. Shut the box top once again and note the volume of the ringing bell.

Discussion: The sound of the ringing bell will be absorbed by the cardboard and the cotton cloth. This will reduce the volume of the sound.

C. LOUDNESS AND SOFTNESS OF SOUND

1. Distance and the Volume of Sound (Demonstration and Activity K-6)

Materials: Door bell, $1\frac{1}{2}$ volt dry cell, and wire.

Procedure: Using a dry cell and wire, connect a bell in a simple circuit. While the bell is ringing, move farther and farther away from it. Is there any change in the volume of the ringing bell?

Discussion: As the distance from the ringing bell increases, the sound becomes softer and softer. Remember, the walls of energy found farther away from the source of the sound are weaker and therefore, the sound is more difficult to hear.

2. Making Loud and Soft Sounds (Demonstration and Activity K-6)

Materials: Large tin can and a wooden mallet or stick.

Procedure: Strike the top of a tin can softly with a wooden mallet or stick. Slowly increase the force used in striking the tin can and note the volume of the sound produced.

Discussion: As the tin can is struck harder and harder, the sound produced becomes louder and louder. Why does this happen? The next demonstration will help you to better understand why.

3. Loudness and Vibrating Objects (Demonstration 3-6)

Materials: Wooden board, two nails, and a heavy rubber band.

Procedure: Stretch a rubber band between two nails as illustrated in Figure

14.3, and put your ear about 12 inches from it. Pluck the rubber band by pulling it about 1 inch to the one side and then releasing it. Note the volume of the sound. Repeat the above procedure several times, *increasing* the distance the rubber band is stretched to one side as it is plucked. Note the volume of the sound each time.

Discussion: When the rubber band is plucked, it vibrates and produces a sound. As the rubber band is plucked harder and harder, the sound becomes louder. The greater the distance through which a vibrating object moves, the louder will be the sound it produces.

4. Loudness and Vibrating Objects (Demonstration and Activity 2-6)

Materials: Tuning fork (Low C 128).

Procedure: Secure a tuning fork which vibrates at 128 cycles per second or less. Tuning forks are labeled with their frequency. Strike the tuning fork gently with your hand so as to produce a very faint sound. Can you see the prongs vibrating? Strike it again, this time a little harder. What has happened to the volume of the sound? Can you see the prongs vibrating?

Discussion: The harder the tuning fork is struck, the louder is the sound produced. It should also be noticed that the harder the tuning fork is struck, the more visible are the vibrations of the prongs. This is due to the fact that the prongs are moving through a greater distance as they vibrate. The greater the distance through which a vibrating object moves, the louder will be the sound it produces.

5. Loudness and Musical Instruments (Demonstration and Activity 3-6)

Materials: Stringed instrument (guitar, violin, etc.).

Procedure: Softly pluck a stringed instrument and listen to the sound. Pluck the string harder and harder and listen to the sound and observe the vibrating string.

Discussion: As the string is plucked harder and harder, a louder sound is produced. The string itself can be seen to vibrate through a greater distance when the string is plucked harder. The greater the distance through which a vibrating object moves, the louder is the sound produced.

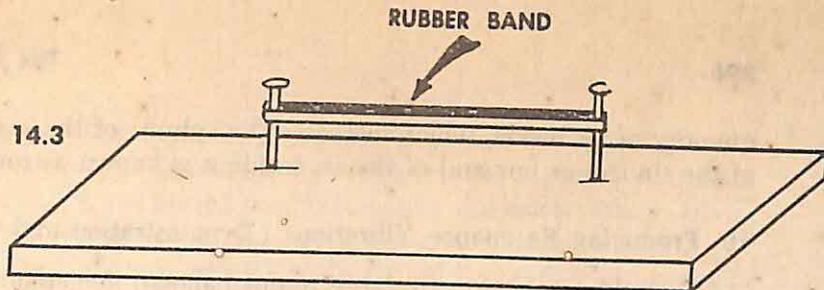
6. Louder Sounds with Sound Boards (Demonstration and Activity 3-6)

Materials: Tuning fork and a tin can or wooden or cardboard box.

Procedure: Strike the tuning fork with your hand and immediately place it on its base atop a tin can or wooden or cardboard box as illustrated in Figure 14.4. What happens? Why?

Discussion: The sound produced by the tuning fork becomes louder when its base is placed atop the tin can or wooden or cardboard box. The vibrations of the tuning fork are transmitted through its base to the container, forcing the sides of the container to vibrate at the same frequency. The larger surface area of the container sets a greater quantity of air in vibration, causing the volume of the sound to be greater. The sides of the container become sound-

Figure 14.3



boards like those of a guitar, violin, or piano. These are all containers designed to increase the volume of the sound produced. The vibration of the sides of the container and the air inside it is known as *forced vibration*.

7. Louder Sounds with Soundboards (Demonstration and Activity 3-6)

Materials: Guitar or other stringed instrument and sand.

Procedure: Lay a stringed instrument flat on a table and sprinkle some grains of sand on the soundboard. Pluck the strings gently and observe the grains of sand.

Discussion: The grains of sand begin to dance up and down. This occurs because the vibrations of the strings are transmitted to the soundboard through the bridge of the instrument. When the soundboard of a container vibrates, it causes the air inside the container to vibrate, setting in motion a greater quantity of air. This increases the volume of the sound. The vibrations of the container walls and the air inside are known as *forced vibrations*.

8. Louder Sounds with Soundboards (Demonstration and Activity 3-6)

Materials: Piano, glass jar filled with water, and a small cork.

Procedure: Set a jar of water on top of a piano and float a small cork in the water. After the water has become motionless, or nearly so, strike a bass note on the piano keyboard and observe the cork floating in the jar of water.

Discussion: When the piano key is struck, the cork begins to bob up and down. The vibrations of the string set in motion by the key are transmitted to the piano soundboard, which is *forced* to vibrate. The vibrations of the soundboard are transmitted to the piano top and then to the jar and the water in it, as is made evident by the motion of the cork. The vibration of the soundboard, piano top, jar, and water caused by the vibrating strings is known as *forced vibration*.

9. Louder Sounds with Soundboards (Demonstration and Activity 3-6)

Materials: Hair comb and tin can or cardboard box.

Procedure: Hold a comb in your hand and run your fingers along its teeth. Hold one end of the comb tightly against the top of a tin can or cardboard box and again run your fingers along its teeth. Is there any difference in the volume of the sound?

Discussion: When you run your fingers along the teeth of the comb while holding it against the tin can or box, the volume is much greater than when you hold the comb in your hand. The vibrations from the comb are transmitted to the larger surface of the can or box, thus setting in motion the large

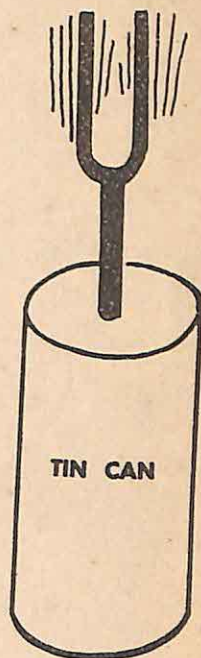


Figure 14.4

quantity of air inside, which increases the volume of the sound. The vibration of the tin can or box and of the air inside it is known as *forced vibration*.

10. Producing Resonance Vibrations (Demonstration and Activity 3-6)

Materials: Large tin can, large round balloon, megaphone, and some sand.

Procedure: Cut off the nozzle end of a large round balloon and stretch the large part of the balloon over the end of a large tin can as illustrated in Figure 14.5. Sprinkle a few grains of sand on the rubber diaphragm as shown. Aim a megaphone in the direction of the rubber diaphragm and slowly hum or sing a musical scale.

Discussion: The grains of sand will begin to dance up and down as the rubber diaphragm vibrates in tune with a specific pitch of your voice. In this case the diaphragm was not *forced* to vibrate by another vibrating object touching it. Instead, it was caused to vibrate by air molecules set in motion by the sound of your voice as the pitch of your voice reached the *natural frequency* of the rubber diaphragm. The natural frequency of an object is that frequency at which it would vibrate if it were struck.

If the sound waves which strike an object are of a frequency which corresponds exactly to the object's natural frequency, the object will begin to vibrate at this frequency. This phenomena is also known as *resonance*.

D. CHANGING PITCH

1. Sounds of High and Low Pitch (Demonstration and Activity K-6)

Materials: Three tin cans of equal diameter but of different height and a wooden mallet or stick.

Procedure: Place three empty tin cans upside down in a row in decreasing order of size. Strike the bottom or closed end of each tin can with a wooden mallet or stick, beginning with the tallest can. Do you notice any difference in the sounds produced by the cans?

Discussion: The sounds produced by the smaller cans are higher in pitch. The *length* of a vibrating object is a determining factor for pitch. In the case of the three tin cans of equal diameter, the length of the vibrating column of air within the cans determines the pitch. The longer the column of air, the lower the pitch. Striking the metal of the bottom of the cans sets the cans and the air molecules within the cans and around the can in motion. The column of air vibrates at the same frequency as the metal of the tin can.

2. Sounds of High and Low Pitch (Demonstration and Activity K-6)

Materials: Two cardboard cylinders open at both ends, both of equal diameter but one twice as long as the other; two rubber balloons; two rubber bands; and a wooden mallet.

Procedure: Cut off the nozzles of two rubber balloons and stretch the remaining part of each balloon over one end of each cardboard cylinder, holding

each in place with a rubber band. When stretching the rubber balloon diaphragms over the ends of the cylinders, it is important to remember that the tension on both should be the same since the amount of tension exerted affects pitch too, as will be investigated in the demonstrations to follow.

Strike each rubber diaphragm (drum) with a wooden mallet. Do the sounds produced have the same pitch?

Discussion: The taller drum has a lower pitch than the shorter one. The length of a vibrating object helps determine its pitch. The column of air in the taller drum vibrates more slowly than the column of air in the shorter drum, producing a lower-pitched sound.

3. Changing Pitch by Changing the Length of the Column of Air (Demonstration and Activity K-6)

Materials: Eight pop bottles and some water.

Procedure: Line up eight pop bottles in a single row. Pour decreasing amounts of water into each bottle, starting at one end and working toward the other as illustrated in Figure 14.6. Blow across the mouth of each bottle until a musical sound is produced. Are the sounds all of the same pitch?

Discussion: The bottle with the least water produces the lowest pitched sound. As the water level increases, the pitch of the sound gets higher. The sound is produced by the vibrating of the column of air inside the bottle, which was set in motion by blowing across the mouth of the bottle. The shorter the column of air, the higher the pitch of the sound produced. Adjust the amount of water in each bottle until the bottles are tuned to a musical scale. Perhaps your music teacher will help you to tune them.

How does a trombone player change the pitch of his instrument? The next activity will help you to find out.

4. A Soda Straw Trombone (Demonstration and Activity K-6)

Materials: Soda straw and a jar of water. (See Figure 14.6a.)

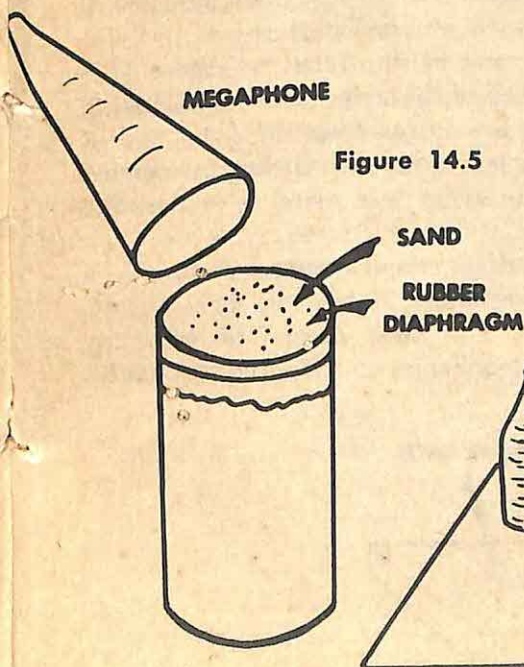
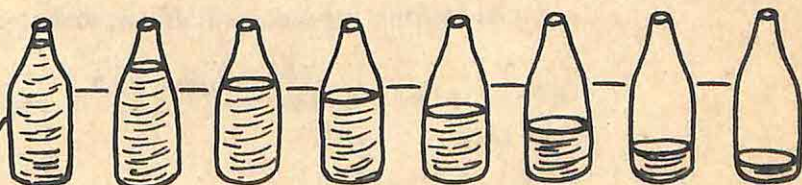


Figure 14.5

SAND
RUBBER
DIAPHRAGM

Figure 14.6



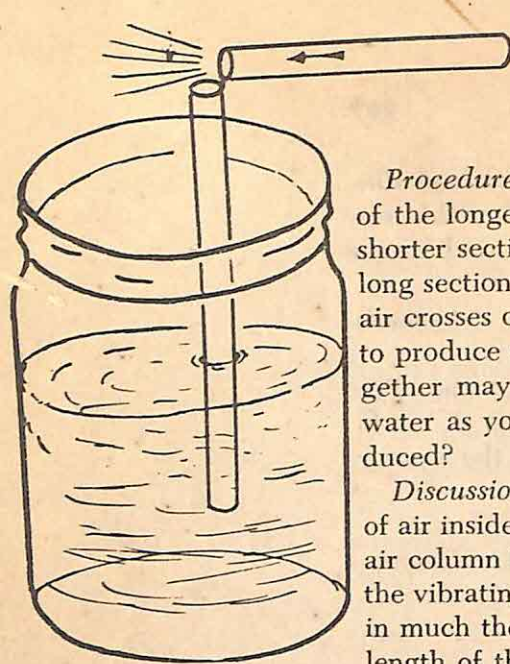


Figure 14.6a

Procedure: Cut a soda straw almost in two and bend it. Put the lower end of the longer portion of the straw in the water and gently blow through the shorter section, as shown, so that the air passes over the upper opening in the long section to produce a sound. A slight adjustment of the angle at which the air crosses over the opening of the long section of the straw may be necessary to produce a sound. Pinching the hinged end of the short section of straw together may also help. Keeping the straw steady, raise and lower the jar of water as you continue to blow. What happens to the pitch of the sound produced?

Discussion: As the jar of water is raised or lowered, the length of the column of air inside the long portion of the straw is changed. The shorter the vibrating air column becomes, the higher is the pitch of the sound produced; the longer the vibrating column of air, the lower the pitch produced. The long straw acts in much the same manner as the slide on a real trombone, which changes the length of the column of air in the instrument. See if you can learn to play a simple tune on your soda straw trombone.

5. A Wind Instrument (Demonstration and Activity K-6)

Materials: Toy wind instrument (tonette).

Procedure: Blow into a toy wind instrument, such as a tonette, with all the finger holes uncovered. Note the pitch of the sound produced. Start to cover the finger holes, beginning at the mouth piece and working toward the far end of the instrument. How does the pitch change? Why?

Discussion: As the finger holes are covered up, the vibrating portion of the column of air in the instrument becomes longer and the pitch gets lower. The longer the column of air the lower the pitch. As the holes are uncovered—proceeding from the far end toward the mouth piece, the column of air becomes shorter again, and the pitch is higher.

6. A One String Instrument (Demonstration and Activity 2-6)

Materials: A board 2 feet long, 2 inches wide and $\frac{3}{4}$ inch thick, fish line, 2 thumb tacks, a small thin piece of wood, and a stringed instrument.

Procedure: Construct a one-string instrument as illustrated in Figure 14.7. Pluck the fish line string and listen to the pitch of the sound. Shorten the string by pressing it tightly to the finger board a few inches from the outer end of the board. Pluck the string again. Shorten it another few inches by moving your finger toward the bridge and pluck the string once more. How does the pitch change?

Discussion: When the string is shortened, it vibrates faster, producing a high-pitched sound. When the string is lengthened, it vibrates more slowly, producing a lower pitched sound. Follow the same procedure with any stringed instrument, such as a guitar, violin, or banjo, and observe the results.

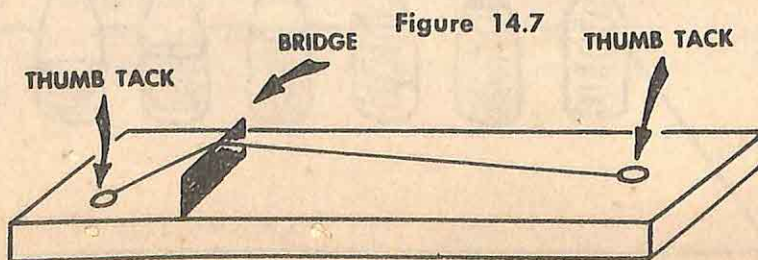


Figure 14.7

7. Changing Pitch by Changing Weight (Activity 2-6)

Materials: Eight pop bottles, water, and a wooden mallet.

Procedure: Follow the procedure suggested in Activity 3 of this section. Tune the pop bottles by adjusting the amount of water in them. Compare the pitch of the sound when you blow across the mouth of the bottle with that when you strike the bottle with a wooden mallet. Are they the same?

Discussion: There will be a distinct difference in the pitches of the sounds made by each bottle when you blow across its mouth as compared with when you strike it. This is because there are two different materials vibrating: a column of air in the first case and a glass bottle in the second.

A bottle with little water in it will have a relatively low pitch when you blow across its mouth. However, when you strike the same bottle with a wooden mallet, it will have a higher pitch than when you blow across its mouth.

A bottle which is almost filled with water will produce a relatively high pitched sound when you blow across its mouth, as compared to the lower pitched sound produced when you strike it with a wooden mallet.

When you blow across the mouth of a bottle with a short column of air in it (one containing more water), a higher-pitched sound will be produced because the air will vibrate faster than it would in a longer column of air in the same bottle. The same bottle when struck by a wooden mallet will produce lower pitched sounds as more water is poured into it because the amount of water in the bottle changes the total weight of the vibrating bottle. The heavier the bottle becomes, the more slowly it will vibrate when struck. The more slowly it vibrates, the lower is the pitch of the sound it produces. The water "becomes a part" of the bottle.

Investigate the wire strings of a piano or other stringed instrument. Which strings produce the higher-pitched sounds? Which produce the lower-pitched sounds? Can you explain why?

8. Changing Pitch by Changing Weight (Activity 4-6)

Materials: Thin glass tumbler and water.

Procedure: Moisten your finger and rub the mouth of a glass tumbler until it begins to "sing." You may need some practice in using the right pressure before you succeed. As you continue to rub the tumbler, have someone pour water into it. What happens to the pitch of the sound?

Discussion: As water is poured into the tumbler, the pitch gets lower and lower. The water is changing the weight of the vibrating glass tumbler. The more water poured in, the heavier the tumbler becomes. The heavier the tumbler becomes, the more slowly it will vibrate. The more slowly it vibrates, the lower will be the pitch of the sound.

9. Changing Pitch by Changing Weight (Demonstration 4-6)

Materials: Stringed instrument or piano.

Procedure: Investigate the relationship between the weight of the strings

of a stringed instrument and the pitches of the sounds they produce. Pluck each string and listen to the pitch of the sound. Open the top of a piano, strike each key, and watch the hammers striking the wire strings. Which strings produce the high-pitched sounds? Which produce the low-pitched sounds?

Discussion: The thick heavy strings will produce the low-pitched (bass) notes, and the thin light strings will produce the high-pitched (treble) notes. The weight of a vibrating object influences its pitch. The heavier the object, the more slowly it will vibrate. The more slowly it vibrates, the lower will be the pitch of the sound it produces.

10. Musical Bells Produce Sounds of Different Pitch (Demonstration and Activity K-6)

Materials: Set of musical bells.

Procedure: Obtain a set of musical bells and examine each one, noting its size. Shake each bell and note the change in pitch as the size of the bells increase. Which bell produces the lowest pitch? Which the highest pitch?

Discussion: The largest bell produces the sound with the lowest pitch. Each bell is made of the same thickness of metal but the sizes of the bells differ so that the larger bells are heavier. The bell with the most weight (the largest bell) produces the sound with the lowest pitch. The heavier an object is, the more slowly it will vibrate. The more slowly it vibrates, the lower is the pitch of the sound it produces.

11. Changing Pitch by Changing Tension (Demonstration and Activity 2-6)

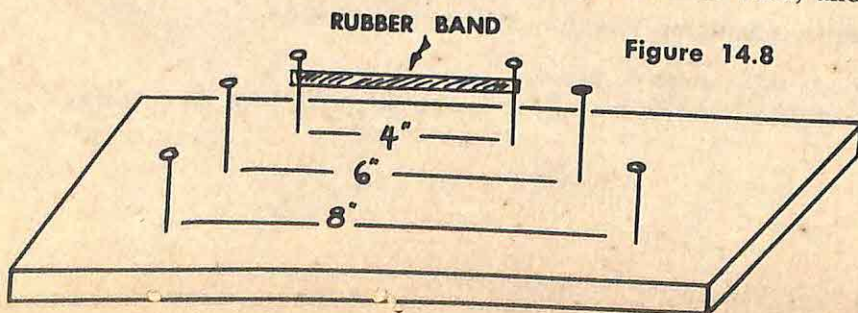
Materials: Rubber band, six nails, and a wooden board.

Procedure: Hammer six nails of equal length firmly into a wooden board as illustrated in Figure 14.8. Stretch a rubber band between the pair of nails, which are 4 inches apart. Pluck the rubber band and listen to its pitch. Shift the rubber band to the next pair of nails, which are 6 inches apart. Pluck the rubber band again and listen to its pitch. Shift the rubber band to the pair of nails which are 8 inches apart, pluck it, and listen to its pitch. Does the pitch of the sound produced by the vibrating rubber band change as it is stretched to a greater length? How does it change?

Discussion: As the rubber band is stretched to a greater distance, the tension is increased. As the tension on the rubber band is increased, the rubber band will vibrate faster. The faster it vibrates, the higher is the resulting pitch of the sound produced.

12. Changing Pitch by Changing Tension (Demonstration and Activity 2-3)

Materials: A board about 2 feet long, 2 inches wide, and $\frac{3}{4}$ inches thick;



a small piece of wood 1 inch long, $\frac{1}{2}$ inch wide, $\frac{1}{8}$ inch thick; 1, 2, and 3 pound weights; fish line; 2 thumb tacks; and a stringed instrument.

Procedure: Construct a one string instrument, using a thin piece of wood for the bridge and fish line for the string. Tie a one pound weight to the loose end of the fish line string and pluck it, listening to the pitch of the sound. Remove the one pound weight and attach a 2 pound weight. Pluck the fish line string again and listen to the pitch of the sound. Is it different? Use a 3 pound weight. Does this make a difference in the pitch?

Discussion: As the weight on the fish line string is increased, the pitch of the sound produced gets higher. Heavier weights increase the tension on the fish line string. As the tension increases, the string vibrates faster. As the string vibrates faster, the pitch gets higher. More tension on a string causes it to produce higher-pitched sounds.

Obtain a stringed instrument, such as a guitar, violin, or banjo. Adjust the tension on the strings. What effect does tightening or loosening a string have on the pitch of the sound it produces? When you tighten or loosen a string on a stringed instrument, you are *tuning* the instrument. Tuning forks are usually used as the standard of pitch for tuning such instruments. You try to match the pitch of a string on the instrument to that of a given tuning fork.

13. Comparing Sounds of the Same Pitch (Demonstration and Activity 4-6)

Materials: Piano, tuning fork (128 cycles per second), tuning fork (256 cycles per second), tuning fork (320 cycles per second).

Procedure: Strike the note of low C on the piano and listen to the pitch of the sound produced. Strike the tuning fork labeled C128 and listen to its pitch. How do they compare? Strike middle C on the piano and listen to its pitch. Now strike the tuning fork labeled C256 and listen to its pitch. How do they compare? Strike middle E on the piano and listen to its pitch. Strike the tuning fork labeled E320 and listen to its pitch. How do the sounds of the piano compare with those of the tuning fork?

Discussion: The wire for the note of low C on the piano vibrates at the same speed as the tuning fork labeled C128. The wire for the note of middle C vibrates at the same speed as the tuning fork labeled C256. The wire for the note middle E vibrates at the same speed as the tuning fork labeled E320. Objects that vibrate at the same rate of speed will produce the same pitch. There may be a distinct difference in the loudness of the sounds, but the pitch will be the same if the piano is in *tune* (e.g., the tension of the wires is adjusted so as to allow the strings to vibrate at the same rate that the tuning forks vibrate).

E. FUN WITH SOUND

1. Making a Xylophone (Demonstration and Activity 4-6)

Materials: Blocks of the same kind of wood in sizes ranging from $\frac{1}{2}$ to $1\frac{1}{2}$ inches thick and from 6 inches to 2 feet in length; newspaper; four rubber bands; a wooden mallet; some modeling clay; and a wood saw.

Procedure: Set an assortment of wooden blocks across two rolled-up newspapers. Tap each block with a wooden mallet and listen to the pitch of the sound produced. Arrange the blocks of wood in order of pitch, from low to high. Try to pick out the ones which produce the pitches of an octave (e.g., eight consecutive notes on the piano) using a piano as an aid. These notes comprise a scale. How can you more closely match the pitches of the blocks to those of the piano scale. This "matching," as you learned in Activity 12 of Section D, is called tuning. What characteristics do the blocks of wood producing low notes have as compared with those producing higher notes?

Discussion: The blocks of wood producing the low pitches are bigger—either longer or thicker—than the blocks of wood producing the high pitches. To better tune the blocks of wood you have selected, that is, to better match the pitches of the blocks to those of the piano, either add weight to or subtract weight from the blocks. The weight of a block of wood can be decreased by cutting it shorter a little bit at a time. Weight can be added by placing a small piece of modeling clay on a block of wood.

2. Playing Musical Bottles with a Vacuum Cleaner (Demonstration and Activity K-6)

Materials: Eight pop bottles, water, and a tank type vacuum cleaner.

Procedure: Set up and tune 8 pop bottles by adding water to or subtracting water from them as discussed and illustrated in Activity 3 of Section "D" of this chapter. Connect the hose of a tank type vacuum cleaner so that the air is being blown out of it instead of being sucked in. Hold the discharge end of the hose at a right angle to the mouth of a pop bottle, aiming it across the mouth of the bottle so that a note is produced. Manipulate the hose from bottle to bottle to play a tune.

Discussion: The moving air from the vacuum cleaner hose sets the column of air in the bottle in motion, causing it to vibrate and produce a musical sound. The shorter the column of air, the higher the pitch of the note produced. The longer the column of air, the lower the pitch.

3. The Roaring Box (Demonstration and Activity K-6)

Materials: Tin can or cardboard box and string.

Procedure: Punch a small hole in the bottom of a tin can or cardboard box. Pass a length of string, knotted at one end to prevent the string from being pulled out, through the hole. Hold the can or box in one hand and take a hold of the string close to the end of the box, keeping it between the fingernails of your thumb and forefinger. Pulling the string taut, allow it to pass between your fingernails until your hand reaches the end of the string.

Discussion: As the string rubs against your fingernails, it vibrates. These vibrations are amplified by the forced vibrations which are set up in the can or box by the string. This accounts for the roaring noise which is heard.

4. Sound Powered Telephones (Demonstration and Activity K-6)

Materials: Two tin cans and a 10 foot length of string.

Procedure: Punch a hole in the center of the closed end of each of two tin cans. Pass one end of a 10 foot length of string through the hole in one tin can and the other end through the hole in the other tin can. Tie a knot on each end of the string to prevent it from slipping out of the tin cans when it is stretched taut between them. (The knots should be on the inside of the cans.) Have a student hold one tin can up to his ear and have another student speak directly into the other tin can. Make sure the string is held taut. What happens?

Discussion: The voice of the student who speaks is clearly heard by the student holding the tin can to his ear. The string transmits the sound vibrations from one tin can to the other. The sound of the student's voice is amplified by forced vibrations created in the tin can held by the other student.

5. Sound Travels Through String (Demonstration and Activity K-6)

Materials: Three spoons and a 4 foot length of string.

Procedure: Tie 3 spoons to a length of string. Hold the ends of the string to your ears. Move your head so that you shake the string and cause the spoons to strike together. What do you hear?

Discussion: The sound vibrations produced by the striking of the spoons are transmitted through the string to your ears.

6. Making a Record Player with a Sewing Needle (Demonstration and Activity 3-6)

Materials: Sewing needle, sheet of construction paper, record player, an old record, and tape.

Procedure: Roll a sheet of construction paper to form a megaphone and secure it with tape. Insert the sewing needle into the small end of the megaphone. Hold the megaphone in your hand, setting the needle in a groove of an old record rotating on a turntable. What happens?

Discussion: The sound vibrations are recorded on a record in the form of various sizes of horizontal ripples. These sound vibrations are transmitted to the needle which vibrates as it rides along the groove. The vibrations of the needle are transmitted to the megaphone, which amplifies the sound in the same manner as a piano soundboard does.

7. Making a Tin Can Record Player

Materials: Large tin can, record player, an old record, and a puncture-type can opener.

Procedure: Cut a hole in a large tin can with a puncture-type can opener and pull out the V-shaped section of the can. Hold the tin can in your hand, setting the V-shaped metal projection in a groove of an old record rotating on a turntable. What happens?

Discussion: The sound vibrations, recorded on the record in the form of various sizes of horizontal ripples, are transmitted to the V-shaped metal projection, which is made to vibrate as it rides along the groove. These vibrations are then transmitted to the larger section of the can which amplifies the sound in the same manner as a piano soundboard.

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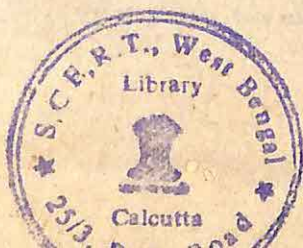
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